IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 4, June 2014.

www.ijiset.com

ISSN 2348 - 7968

Design of Low Power Ring VCO and LC-VCO using 45 nm Technology

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Abstract

"CMOS" refers to digital circuit design, and the processes used to implement that design on integrated circuits. CMOS circuits in VLSI consume less power when static. This paper presents a complementary metal–oxide–semiconductor (CMOS) ring oscillators and LC VCO and is brief study of high performance VCO on 45 nm technology to achieve the desired objectives such as both non linear and linear operations. The circuits used in this paper is a modified design of VCO. In the design more significance is given on power consumption and high frequency at output. Two VCO topologies are compared on the basis of power consumption and output frequency. In this paper, 45 NM CMOS technology provide less power consumption and high output frequency as compare to other CMOS technology.

Keywords: **CMOS, LC-VCO, Power Consumption, VLSI,VCO.**

1. Introduction

Accurate frequency or time reference signals are required practically in every analog, digital or mixed-signal design [1]. In recent years wireless communication market was still growing. Such situation increased the demand for low cost integrated transceivers. Because communication standards are becoming more complicated, requirements for such transceiver parameters as noise, linearity and power consumption are at the limits of technology. This forces RF IC designers to explore design trade-offs very deeply for each circuit, which makes design process much longer. This at the end has an impact on transceivers price. To help the designer, aiding tools should be created in order to make the design process easier and faster. VCO design involves the simultaneous satisfaction of a number of design criteria as well as power optimization, mainly for portable applications.

There are growing demands in millimeter-wave and upper millimeter-wave electronics for various applications, especially V-band radio (57 to 64 GHz according to FCC). V-band systems are primarily used for high capacity; short distance (less than 1 mile, because high oxygen absorption in this band) communications The use of other frequency bands beyond 60 GHz offers advantages such as smaller antenna and chip sizes and unlicensed spectrum usage.[2]

This paper describes a low-power LC-VCO design with signal outputs of 77-GHz and ring VCO with signal output 11-GHz. The LC-VCO design is based on an on-chip symmetrical spiral inductor and a differential varactor. The design tool CADENCE VIRTUOSO was used. The CMOS process must be used to keep costs low. The power consumption was kept low with differential LC tanks. The circuit was implemented in a 45nm CMOS process.

2. Design Methodology

In the design, a simple three stage Ring oscillator and LC-VCO is explained with its structure.

2.1 Design of Three stage Ring VCO

The design type of VCO selected for this work is of the "Current Starved" type [3]. This is essentially a ring oscillator, contain of an odd number of inverters each biased by a complimentary pair of transistors operating as current sources as shown in Fig. 1. The function of the current sources is to limit the amount of current supplied to the inverter. An additional pair of transistors acts as an input stage with very large input impedance [1].

To determine the operating frequency of the VCO, we note that the total capacitance (Ctot) on the drains of the inverter transistors is given by the sum of the input (Cin) and output capacitances (Cout of the inverter:

$$C_{tot} = C_{out}\, C_{in}$$

$$C_{tot} = \frac{5}{2} C_{ox} W_p L_p W_n L_n$$

where Wn and Wp are the widths of the transistors and Ln and Lp are their lengths. Cox is the gate oxide capacitance per unit area.

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 4, June 2014.

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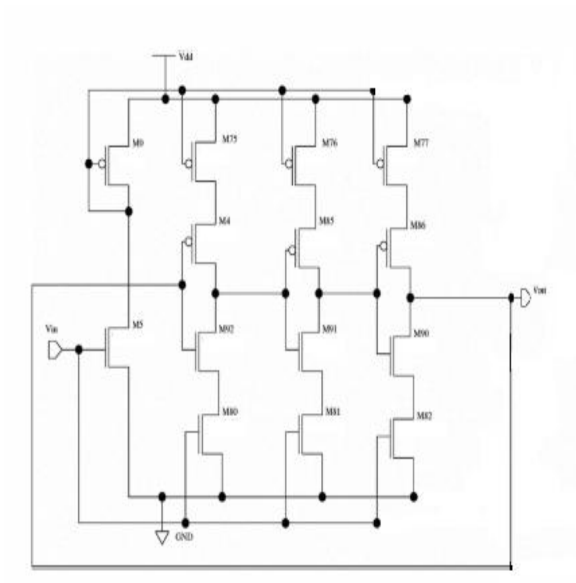

Figure 1 Three Stage Ring VCO

The total time required to charge and discharge the capacitance of an inverter stage is then given by:

$$T_{total} = C_{total} \frac{V_{DD}}{I_{DD}}$$

where V_{dd} is the power supply and I_d is the current flowing through the inverter.
If there are N inverters in the oscillator (where N is an odd number,) the frequency of oscillation is given by:

$$f_{osc} = \frac{1}{NT} \frac{1}{C_{total}} \frac{I_d}{V_{DD}}$$

It is clear from this expression that the frequency of oscillation is dependent not only on the size and number of inverters but is also proportional to I_d which can be controlled via the input voltage Vin.

We used the MOS2V models for our design. Simulation results are shown in Fig. 2.

Two basic performance criteria were identified:

1) The frequency response with respect to input voltage.
2) The total power consumed by the VCO

The fundamental parameters under design control are the sizing of the various transistors (W / L ratio) and the oxide thickness (Tox) used in the process. Clearly higher values of Tox will reduce the leakage power but will also reduce the frequency of operation. The optimization problem then becomes quite involved due to the number of variables involved:

The gate oxide thickness Tox.

- β_1 - W / L ratio for the PMOS inverter transistors.
- β_2 - W / L ratio for the NMOS inverter transistors.
- β_3 - W / L ratio for the PMOS current starve transistors.
- β_4 - W / L ratio for the NMOS current starve transistors.

Thus we have 5 input factors and 2 desired responses.

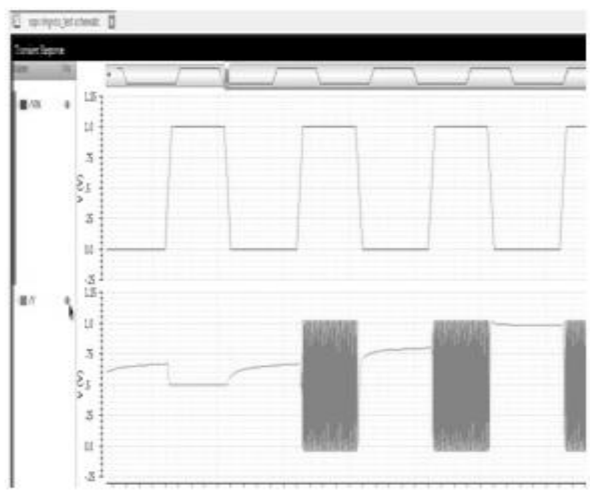

Figure 2 Transient Response of Ring VCO

2.2 LC VCO

Ring oscillator and LC oscillators are the two most commonly used circuit oscillators. Though the tuning range of ring oscillators is more than that of LC oscillator, due to the low phase noise requirements, LC oscillator are used in GSM systems. The LC tank oscillators in the circuit consist of a spiral inductor and moscap.

As shown in Figure 3, the VCO is a simple NMOS cross-coupled pair [4]. The NMOS transistor width and length are sized to obtain sufficient negative resistance. A PMOS transistor is used as the tail current source. Its relatively large gate area reduces the 1/f noise and close-in phase noise of VCO. The PMOS transistor current can be controlled in a PLL with the loop filtered control voltage [5] to change the DC drain voltage of cross-coupled pair so that the VCO tuning range is enhanced [4]-[6]. A 2-stage tapered buffer with 3-mA DC bias current/side is used so that the smaller sized 1st stage transistor reduces the capacitive loading of the LC-tank [5]. The buffer has its own supply voltage and the VCO output power can be adjusted by changing the buffer supply.

The LC resonant tank is formed using lumped elements instead of distributed elements to save the circuit area [5]. The tank consists of a single loop circular inductor, a pair of accumulation-mode n-well MOS varactors and the parasitic capacitances associated with the NMOS cross-coupled transistors and buffer transistors.

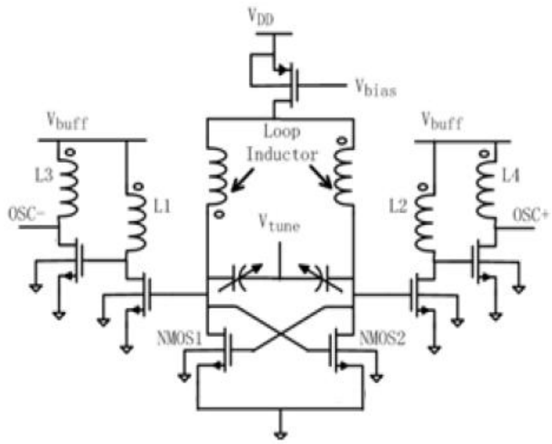

Figure 3 LC-VCO

Simulation result is shown in figure4. It is clear from figure that both the output are in phase.

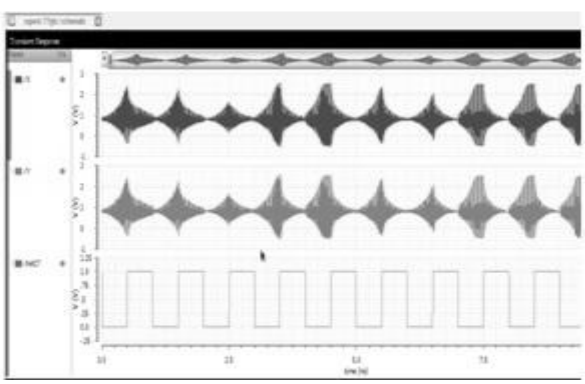

Figure 4 Transient Response of LC-VCO

Experimental Results & Discussion:

The simulation of a high performance three stage Ring VCO and LC-VCO circuit was carried out and is shown in fig2 and fig. 4 resp. In this simulation study, the performance of VCO circuit such as, frequency and power consumption were revealed. The average power consumption of ring VCO is 11.64µw and LC-VCO is 39.55µw. the frequency at the output of ring VCO and LC-VCO are 11 GHz and 77 GHz respectively. It was verified that, the frequency oscillation achieved in three stage ring VCO is more then LC-VCO. The main drawback of Ring oscillator is the great influence of temperature and VDD supply on the stability of the oscillations.

Conclusion

The two different topology of VCO has been designed in CADENCE Virtuoso tool using 45nm CMOS technology. Ring VCO consume less power then the LC-VCO. In Ring VCO, we achieve high oscillation at output. In the estimated design of VCO, main focus is given on power consumption and output frequency. A brief study of high performance of three stage Ring VCO and LC-VCO on 45 nanometer VLSI technology is presented, where a reasonably good frequency stability and voltage stability was obtained experimentally through simulation.

Table

Parameter	Ring VCO	LC-VCO
Technology	45 NM	45NM
Operating Voltage	1V	1.1V
Output Frequency	11 GHz	77GHz
Power consumption	11.64µw	39.55µw

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