International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 12, December - 2013

Compact Design of Ring and Voltage Controlled Oscillators for Wireless Devices

A. Sharma, M. S. Manohar, G. Mishra and D. S. Rathore
Electronics and Communication Engineering
The LNM Institute of Information Technology, Jaipur

Abstract

Portability and power efficiency of wireless devices became main concern over the few decades. Voltage Controlled Oscillator (VCO) is an essential part of all wireless systems. Designing a VCO with less area and low power dissipation is aimed for efficient wireless devices. This paper describes performance comparison between ring oscillator and Current Starved VCO for various wireless systems including Wi-Fi, WLAN, WPAN, Bluetooth, ZigBee band and all other working at 2.4 GHz frequency. Oscillators are designed in 90nm and 65 nm technology and compared on the basis of design experiment and qualitative evaluation. All the designs are implemented in EDA tool microwind 3.1.

1. Introduction

Wireless Communication is fastest developing technology in modern world which is responsible for flexibility and mobility. Device portability and power consumption are the two crucial parameters for high performance wireless devices. Short range wireless communication is held by Wi-Fi, WLAN, WPAN, Bluetooth and ZigBee Band which are corresponding to the IEEE 802.15.1, 802.15.3, 802.15.4, and 802.11a/b/g standards. And all these systems works around 2.4 GHz frequency range. ZigBee is one of the newest technologies enabling Wireless Personal Area Networks (WPAN). ZigBee is the name of a specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4 standard. The technology is intended to be simpler and cheaper than other WPANs such as Bluetooth [1].

Ring oscillators consist of series of delay stages, which are more important in comparison to other monolithic oscillators [2]. On the performance point of view, ring oscillators results are better than relaxation oscillators [3], although relaxation oscillators easily achieve very wide tuning range but they are not so power efficient. LC tank oscillator performs better in phase noise with low power consumption. However, there are some disadvantages. Tuning range of LC oscillators is low and their phase noise performance highly depends on quality factor. Ring VCOs are always the favoured type of oscillators used in Mixed/Signal environments due to their compact size, digital compatibility and ease of porting [4].

Voltage Controlled Oscillator (VCO) is most essential component of all wireless communication systems, providing frequency translation in RF Circuits and periodic signals for timing in digital circuits. The VCO core is based on an inverter-type ring oscillator supplied by a current coming from the voltage-to-current converter [5]. The VCO consists of four-stage fully differential delay cells performing full switching. VCO's are used in applications such as clock recovery circuits for serial data communications [6], [7], disk-drive read channels [8], on-chip clock distribution [9], and integrated frequency synthesizers [10], [11]. The VCO performance in terms of phase noise, tuning range, and power dissipation determines many of the basic performance characteristics of a transceiver.

The rest of the paper follows as Ring oscillator and its designing in section-II, Current Starved VCO Design in section-III, section-IV Simulation results using Microwind 3.5 layout design tool and discussion over the results is mentioned and section-V concludes the paper.

2. Design of Ring Oscillator

A ring oscillator is cascaded combination of delay stages, with the output of last stage fed back to the input of first. For a single-ended delay stage oscillator shown in fig. 1, an odd number of stages are necessary for dc inversion but it will not oscillate with a single inverter with output feedback to input.[12] Therefore, the oscillator must have n delay stages to provide phase shift of π in time $m\tau d$ where τd is propagation delay of each stage. Thus the frequency of oscillator is given by :

$$f0=1/2m\tau d \qquad (1)$$

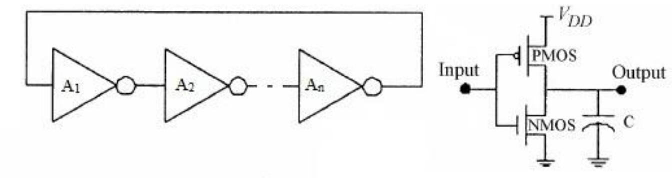

Fig. 1. Single-ended Ring Oscillator

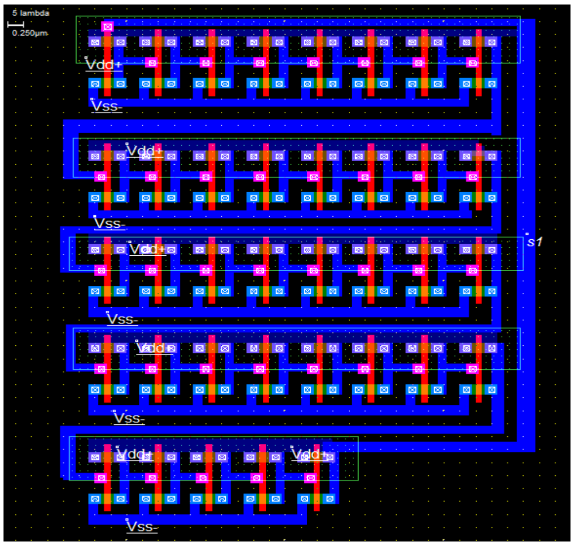

Fig. 2. Layout of Ring Oscillator in 90nm technology

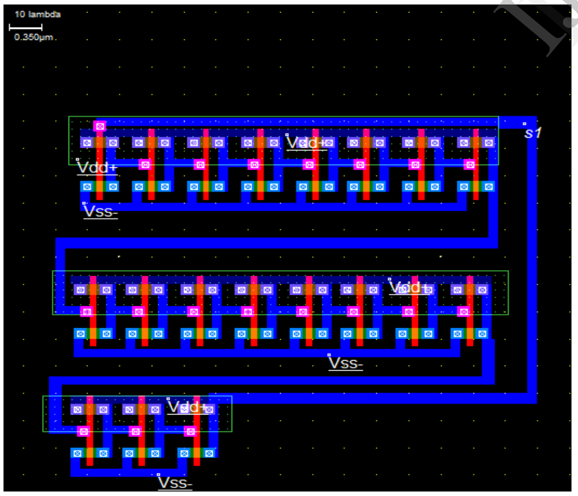

Fig. 3. Layout of Ring Oscillator in 65nm technology

The usual implementation consists in a series of five up to one hundred chained inverters. One inverter in the chain may be replaced by a NAND gate to enable the oscillation. Fig.2 show a 37 stage ring oscillator in 90 nm technology to provide frequency required to operate wireless system. Fig. 3 shows a 19 stage ring oscillator in 65nm technology to run wireless devices. Ring oscillator in 90nm technology requires more number of stages as compared to 65nm technology for generation of 2.4 GHz frequency.

3. Current Starved VCO

A voltage-controlled oscillator or VCO is an electronic oscillator designed to be controlled in oscillation frequency by a voltage input. It generates a clock with a controllable frequency from -50% to +50% of its central value. The frequency of oscillation is varied by the applied DC voltage “Vcontrol”. Current Starved VCO is a type of VCO based on ring Oscillator with extra CMOS acting as current source for the inverters.

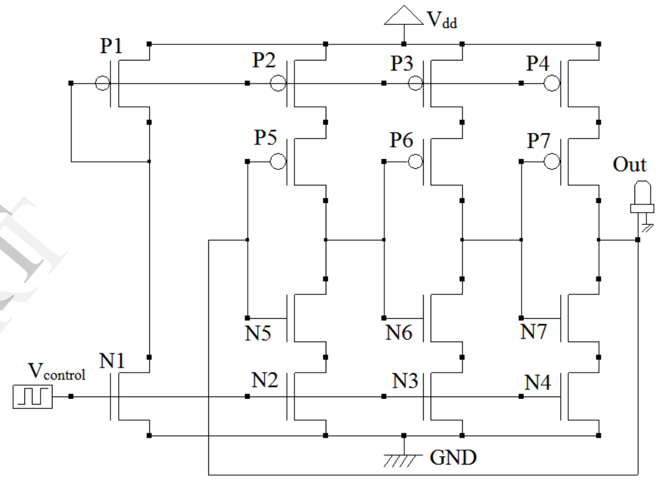

Fig. 4. Voltage Controlled Oscillator

The operation of current starved VCO is similar to the ring oscillator. Fig. 3 shows the three stage current-starved VCO design [13]. PMOS P5 and NMOS N5 forms an inverter, and similarly P6, P7, N6 and N7 construct inverter while upper PMOS P2 and lower NMOS N2 operate as current sources. The current sources (P2 and N2) limit the current available to the inverter (P5-N5). The current-starved inverter chain uses a voltage control Vcontrol to modify the current that flows in the N1, P1 branch. The current through N1 is mirrored by N2, N3 and N4. The same current flows in P1. The current through P1 is mirrored by P2, P3 and P4. Consequently, the change in Vcontrol induces global change in the inverter currents, and acts directly on the delay. A higher number of stages are commonly implemented, depending on the target oscillating frequency and consumption constraints.

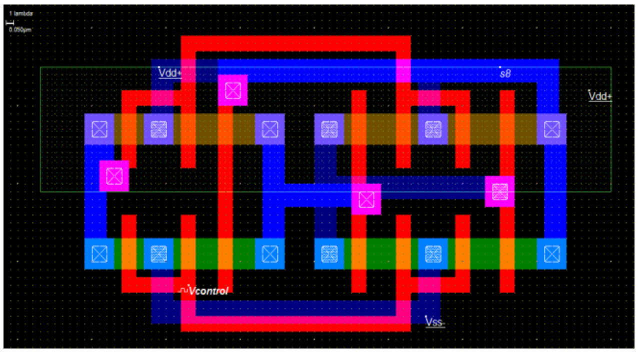

Fig. 5. Layout of Voltage Controlled Oscillator

Output frequency of Current Starved VCO reaches around 2.4GHz when applied control voltage is 0.262V in 90nm technology and in 65nm technology it requires control voltage 0.267V. Recently, because of the increasing demand for lower cost and higher integration, CMOS VCO's have been continuously enhanced. Some CMOS VCO's have challenged the maximum operating frequency of several gigahertz[14].

4. Simulation Results

Modern CMOS designing is very much based upon reducing power consumption and stability of designed circuit. In this work both oscillators are compared for power dissipation and output frequency in 90nm and 65nm technology. Ring and Voltage Controlled Oscillators designs are simulated on microwind 3.1 software. The simulation shows varying frequency with respect to time. Power dissipation, area occupied and current consumption is observed for frequency near to 2.4 GHz for wireless operations. Ring Oscillator with 37 inverter stages generates frequency 2.46 GHz in 90nm technology where as in ring oscillator with 19 inverter stages generate 2.50 GHz frequency in 65nm technology. For Voltage Controlled Oscillator the output signal frequency reaches 2.4 GHz at control voltage equal to 0.262V in 90 nm technology while in 65nm technology it can achieve same frequency at 0.268V.

The results are obtained for a control voltage range of 0.20V to 1.20V because the maximum voltage (Vdd) possible in the design is 1.20V in 90nm technology and the threshold voltage of the transistor is 0.20V. The circuits will not work proper below 0.20V as the threshold condition of the transistor is not satisfied. Oscillation obtained for a control voltage, Vcontrol equal to 0.262V in 90nm technology by ring oscillator shown in fig. 6 and by voltage controlled oscillator shown in fig. 7.

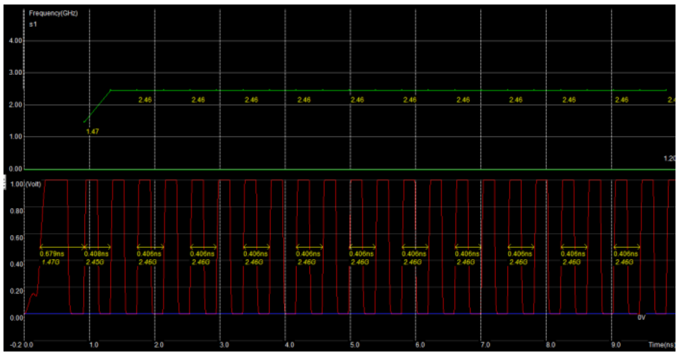

Fig. 6. Simulation Results for Ring Oscillator in 90nm technology

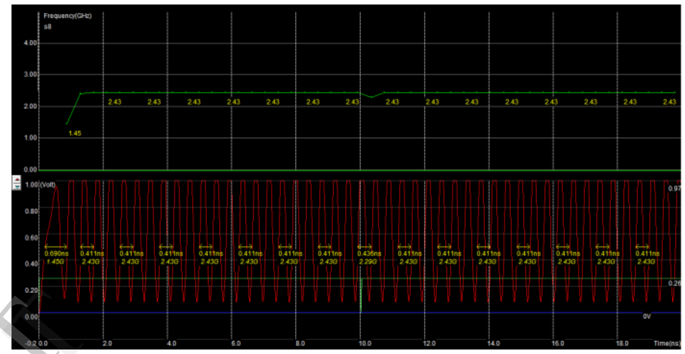

Fig. 7. Simulation Results for Voltage Controlled Oscillator in 90nm technology

Results for ring oscillator with 37 inverter stages and for voltage controlled oscillator with Vcontrol = 0.262V in 90nm technology are shown in Table I on basis of area, power, current and output frequency.

TABLE I. Simulation results for 90NM technology

Parameter	**Oscillators**	
	Ring Oscillator	***Voltage Controlled Oscillator***
Area occupied	58.2µm^2	7.3µm^2
Power consumption	0.154mW	16.010µW
Current estimation	Idd max = 0.213mA Idd avg = 0.128 mA	Idd max = 0.032mA Idd avg = 0.013 mA
Frequency	2.46GHz	2.43 GHz

The results are obtained for a control voltage range of 0.20V to 0.70V because the maximum voltage (Vdd) possible in the design is 0.70V in 65nm technology and the threshold voltage of the transistor is 0.20V. The circuits will not work proper below 0.20V as the threshold condition of the transistor is not satisfied. Oscillation obtained for a control voltage, Vcontrol equal to 0.268V to produce output frequency 2.44GHz for wireless frequency band in 65nm technology by ring oscillator shown in fig. 8 and by voltage controlled oscillator shown in fig. 9.

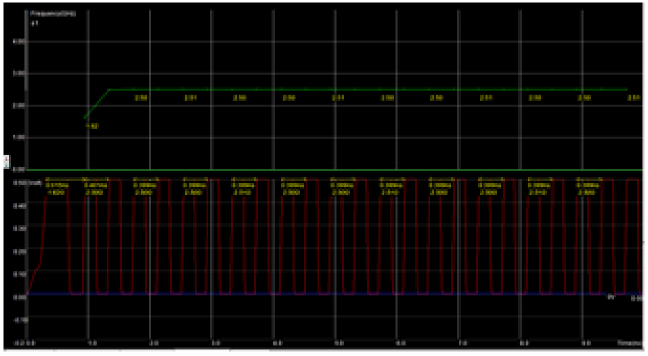

Fig. 8. Simulation Results for Ring Oscillator in 65nm technology

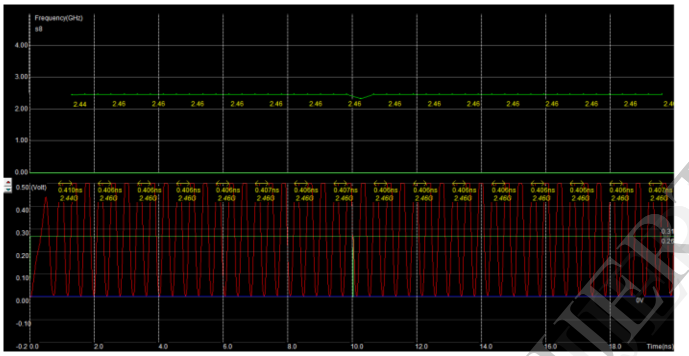

Fig. 9. Simulation Results for Voltage Controlled Oscillator in 65nm technology

Results for ring oscillator with 19 inverter stages and for voltage controlled oscillator with Vcontrol = 0.268V in 65nm technology are shown in Table II on basis of area, power, current and output frequency.

TABLE II. SIMULATION RESULTS FOR 65NM TECHNOLOGY

Parameter	**Oscillators**	
	Ring Oscillator	***Voltage Controlled Oscillator***
Area occupied	14.4µm^2	3.6 µm^2
Power consumption	14.945µW	2.811µW
Current estimation	Idd max = 0.036mA Idd avg = 0.021mA	Idd max = 0.009mA Idd avg = 0.004mA
Frequency	2.50 GHz	2.46 GHz

The behavior of output frequency of Voltage controlled oscillator in 90nm and 65nm technology is shown in Table III with varying control voltage. Fig.10 shows graphical representation of behavior shown in Table III.

TABLE III. SIMULATION RESULTS FOR VCO

Control Voltage (in volts)	**Voltage Controlled Oscillators**	
	Frequency (in 90nm) (in GHz)	***Frequency (in 65nm) (in GHz)***
0	-	-
0.1	-	-
0.2	0.44	0.63
0.3	3.96	3.66
0.4	8.20	6.38
0.5	11.56	7.47
0.6	13.70	8.01
0.7	14.95	8.32
0.8	15.72	-
0.9	16.18	-
1.0	16.50	-
1.1	16.75	-
1.2	16.95	-

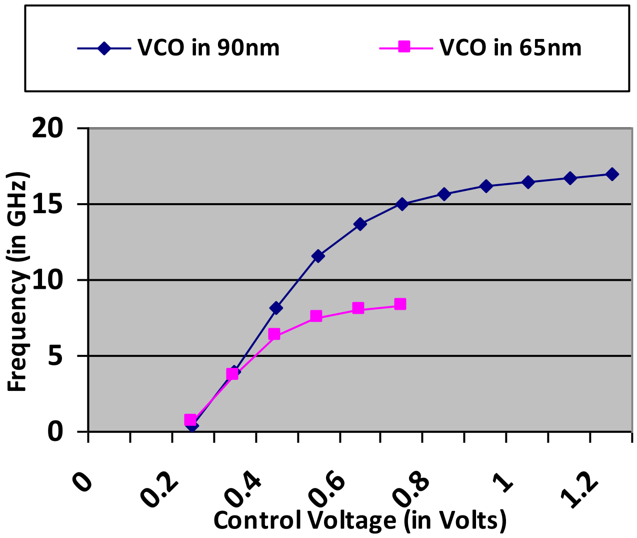

Fig. 10. Graphical Representation of Output Frequency vs Control Voltage

5. Conlusions

The performance of two oscillators, Ring and Voltage Controlled designs are compared for Wi-Fi and Zigbee band on the basis the design experiment and qualitative evaluation in 90nm and 65nm technologies. Power consumption for Voltage Controlled Oscillator is less than Ring Oscillator in both 90nm and 65nm technology. Area and Current estimation for Voltage Controlled is less than Ring oscillator. Above results shows that Voltage Controlled Oscillator is better than Ring Oscillator for operation of wireless systems.

6. Refrences

[1] Bhavneet Sidhu, Hardeep Singh, and Amit Chhabra "Emerging Wireless Standards - WiFi, ZigBee and WiMAX" World Academy of Science, Engineering and Technology 25 2007.

[2] T.Cao, D.T. Wisland, T.S. Lande, and F.Moradi, "Low-voltage, low power, and wide tuning range VCO for frequency delta-sigma modulator", *IEEE conference NORCHIP*, pp. 79-84, Nov. 2008.

[3] Catli and M.M. Haskell, "A 0.5V 3.6/5.2 Ghz CMOS multi-band VCO for ultralow-voltage wireless applications," IEEE International Symposium on Circuits and Systems, pp. 996-999, May 2008.

[4] A. Saad and K. M. Sharaf, "A Fully Integrated 2.4GHz CMOS Frequency Synthesizer Using a Ring –Based VCO with Inductive Peaking", IEEE Int. Symp. Circuits Syst. (ISCAS'07), , pp. 2566-2569, May 2007.

[5] R. Vincent, "A High-Speed, Low-Power Clock Generator for a Microprocessor Application" IEEE Journal of Solid-State Circuits, Vol. 33, No. 11, pp. 1634-1639, Nov. 1998

[6] C.H. Park, O. Kim, B. Kim, "A 1.8 GHz self-calibrated phase locked loop with precise I/Q matching ",IEEE J. Solid-State Circuits, vol.36, page 777-783, 2001.

[7] L. Sun and A. Kwasniewski, "A 1.25 GHz 0.35-m monolithic CMOS PLL based on a multiphase ring oscillator," IEEE J. Solid-State Circuits, vol.36, page 910-916, 2001.

[8] J. Savoi and B. Razavi, "A 10 Gb/s CMOS clock and data recovery circuit with a half rate linear phase detector," IEEE J. Solid-State Circuits, vol.36, page 761-767, 2001.

[9] C.K.K. Yang, R. Farjaid-Rad, M.A. Horaowitz , "A 0.5m CMOS 4.0 Gbits/s serial link transceiver with data recovery using oversampling," IEEE J. Solid-State Circuits, vol.33, page 713-722, 1998.

[10] M. Alioto , G. Palumbo, "Oscillation frequency in CML and ESCL ring oscillators," IEEE Trans. Circuits Syst. 1, vol. 48,page 210-214, 2001.

[11] B. Razavi, "A 2GHz 1.6mW phase locked loop," IEEE J. Solid-State Circuits, vol.32, page 730-735, 1997.

[12] S. Docking, M. Sachdev, "A Method to Derive an Equation for the Oscillation Frequency of a Ring Oscillator", *IEEE Trans. on Circuits and Systems-I: Fundamental Theory and Applications*, vol. 50, pp. 259-264 Nov. 2003.

[13] R. J. Baker, H. W. Li & D. E. Boyce, "CMOS Circuit Design Layout, and Simulation", *IEEE Press*, 2002.

[14] Y. Jeong, S.-H. Chai, W.-C. Song, and G.-H. Cho, "CMOS current controlled oscillator using multiple-feedback-loop ring architecture," in ISSCC Dig. Tech. Papers, San Francisco, CA, Feb. 1997, pp. 386–387.