HIGH PERFORMANCE VCO FOR LOW POWER RF TRANSMITTER-A Review

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ABSTRACT
A typical RF transmitter requires maximum start up time. The transient energy during the startup can be higher than the energy required by the electronics during the actual transmission. In order to reduce start up energy consumption, reduce the power dissipation in transmitter. This power dissipation in transmitter is reduced by lowering the phase noise of VCO.In this paper comparison is made between different architectures of CMOS LC tank VCO such as differentional cross coupled, complementary cross coupled ,cross coupled with pseudo resistance and Quadrature VCO with reconfigurable LC tank which are used to design high performance LC tank VCO for low power RF transmitter .From the comparison table 1,we note that complementary cross coupled LC VCO provides best tuning range i.e.21% and cross coupled with pseudo resistance LC VCO provides lowest phase i.e.-125.5 dBc/Hz among the other VCOs, it also has minimum power consumption, highest tuning range and best FOM i.e.-190.84.

Keywords
Voltage-controlled oscillator (VCO), CMOS, low power, low phase noise, FOM.

1. INTRODUCTION
A typical RF transmitter contains core network (source), transport, baseband processor modem, up-converter, mixer, oscillator, power amplifier, frequency synthesizer etc. All blocks of front end except power amplifier, the frequency synthesizer usually consumes most power. Transmitters require a significant overhead in terms of time and energy dissipation to go from the sleep state to the active state. Typical start-up time is on the order of 100µs or more, while the transmit on-time is less than that. This means that the transient energy during the startup can be higher than the energy required by the electronics during the actual transmission.

Following are the basic RF parameters required for various targeting applications such as Time/frequency references used for proper channel selection, short start up time of RF transmitter used to reduce power consumption, high data rate allows low duty cycle, sufficient output power of transmitter used to the connect between different WBAN and maximum transmitter efficiency used to improve performance.
From these parameters, it is come to know that power consumption depends upon start up time of RF transmitter.
The solid line [6] shows that as the start-up time increases, the energy consumption is dominated by the start-up transient and not by the transmit on-time.

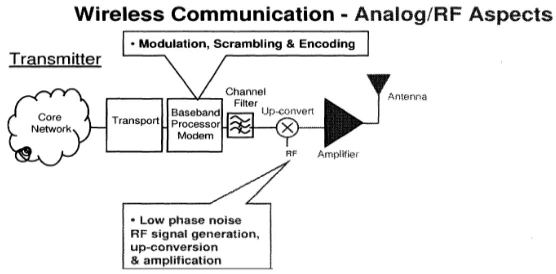

Figure1: wireless communication analog/RF aspects

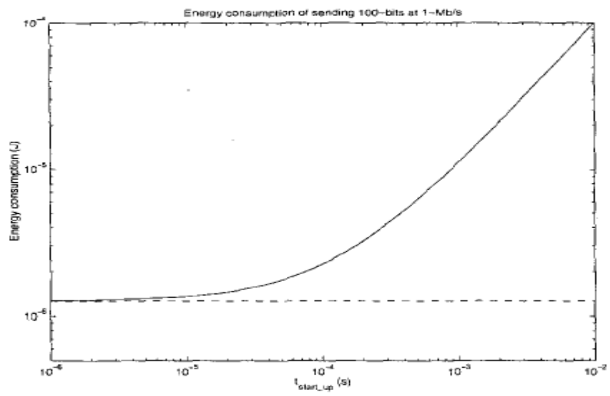

Figure 2: Effect of start-up transient

Hence it is essential to minimize the start-up time in order to reduce power consumption. The energy consumption is depended on the power dissipation of the transmitter. This power dissipation of the transmitter can be lowered by reducing the performance requirements of critical transmitter components - for example, the phase noise requirement of the VCO and the frequency offset error of the frequency synthesizer [1]. From some of the literatures [6,8] it is concluded that in order to reduce start up time of RF transmitter, lower the phase noise of LC tank VCO.

2. LC VCO
Among of the RF blocks [3], the CMOS LC-VCO is one of the most difficult circuit to integrate for the following reasons: 1) poor quality factor of the monolithic inductor; 2) limited tuning range of the varactor and 3) poor flicker noise in CMOS Technology. RF designers try to design low phase noise oscillators, while their design complexities carry various challenges. Low phase noise is one of the most important criteria in a VCO while is in conflict with power consumption.
So, achieving the low phase noise and simultaneously low power VCO is an open challenge. Many studies are reported considering phase noise mechanisms and many papers explain about how one can design an oscillator with low phase noise by selecting the appropriate topology, resonator and coupling networks.

3. VCO DESIGN OBJECTIVE

The objective of designing of high performance LC tank VCO,is to reduce the start up time of RF transmitter to conserve energy. This will offers low phase noise, low power consumption and best FOM of LC tank VCO.The phase noise is one of the most important parameter in a VCO and is in conflict with power consumption [3]. Flicker and thermal noises generated by the circuit elements are fundamental sources of the phase noise. The thermal noise sources will be converted into phase noise because of the switching mechanism of the cross-coupled pair. A number of models have been developed to estimate the phase noise of an oscillator. Leeson's model defines the phase noise at a given offset frequency, Δw, from the center frequency as bellow [3]

$$L[\Delta\omega] = 10log\left[\frac{2FKT}{Psig}\left[1+\left(\frac{\omega_o}{2Q\Delta\omega}\right)^2\right]\left(1+\frac{\Delta\omega_{1/F}}{|\Delta w|}\right)\right] \quad (1)$$

Where L[Δw] is the phase noise at offset frequency Δw from the operating frequency $w_{0,}$ F is an empirical fitting factor, and Q is quality factor of the LC-tank.
The figure of merit defined [3] as

$$FOM=L[fm]+10log[(fm/fo)^2 Pdc] \quad (2)$$

From this it is seen that FOM depends on the phase noise and power consumption.

4. BASIC RESONANCE CIRCUIT

One of the most important parts of an LC VCO is the LC resonant tank. The resonant tank is the basic configuration to control the oscillation frequency of an LC oscillator. The basic tank configuration of an LC oscillator is as seen in Fig. 3. From Fig. 3, L represents the inductance of the tank while C represents the capacitance. Both RL and RC are the parasitic of the inductance and capacitance respectively.

In order for the resonance tank to resonate without any loss coming from parasitic, the parasitic resistance and capacitance coming from both the inductor and resistor need to be compensated. As for the compensation for parasitic resistance, a negative resistance, -R is formed in the tank in order to cancel out both of the parasitic resistances. However, in a real form, negative resistance does not exist. a negative resistance is formed by cross-coupling transistors that are connected to the resonant tank.

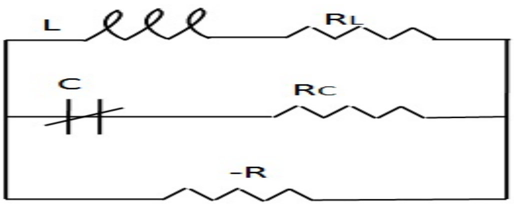

Figure 3: Basic LC resonant tank

By cross-connecting the output to the input of the oscillator, negative resistance that has the same conductance as the transistor's transconductance (g_m) is created.

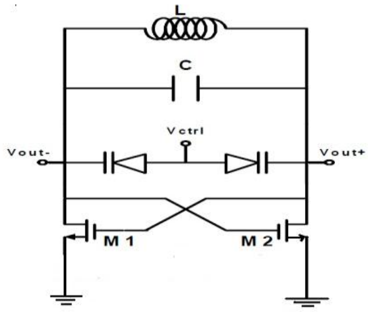

Figure 4: Cross-Coupled Oscillator

The phase noise of a LC-VCO is inversely proportional to the Q^2[3], where Q is the equivalent quality factor of the LC-tank. Since the quality factor of varactors are more than inductors, thus the quality factor of inductor plays dominant role in the Q of tank. The CMOS inductors in RF circuits suffer from low quality factor. So, if one can increase the Q of the LC-tank, the phase noise will be improved. For this goal, we have used added negative transconductance technique in the proposed LC-VCO. The quality factor of a LC-tank can be expressed as bellow:

$$Q=1/Gtot \sqrt{C/L} \quad (3)$$

Where Gtot is the transconductance of the LC-tank that can be confined with quality factor of the inductor. We can express Gtot as follow:

$$Gtot=Gp-G_N \quad (4)$$

Where GN is the added negative conductance to the circuit that can decrease Gtot and therefore increase Q of the LC-tank.

5. ARCHITECTURES AND PERFORMANCES

There are different architectures used to design LC tank VCO.The choice of best architecture depends upon which architecture should be provided low phase noise, power supply, power consumption and FOM.There are four different architectures has been explained in this paper such as differential cross coupled, complementary cross coupled, cross coupled with pseudo resistance and Quadrature VCO with reconfigurable LC tank.

5.1. Differential cross coupled LC tank VCO

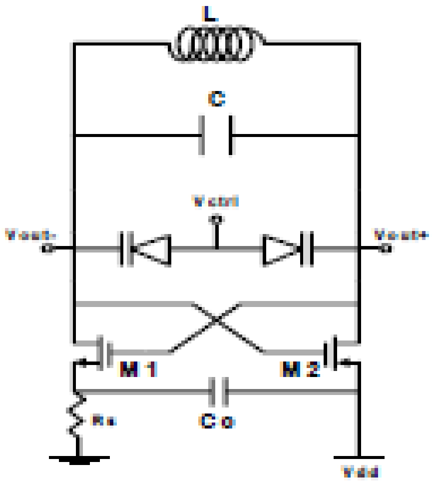

Figure 5: differential cross coupled VCO

In [1] differential cross coupled LC tank VCO, the negative transconductance is generated as

$$Gn = \frac{gmp.gmn}{gmp+gmn+Rs.gmp.gmn} \quad (5)$$

Where

Gn=negative conductance which depends on
g_{mp}=>transconductance of PMO,
g_{ms}=>transconductance of NMOS
Rs=>source resistor

Gn (negative conductance) is formed as a combination of g_{mn} (transconductance of NMOS) and g_{mp} (transconductance of PMOS) and source resistor Rs. Rs not only maintains the balanced DC conditions but also makes this VCO have the small-signal schematic like the conventional LC-VCO by proper selection of N- and P MOSFETs. The resistor Rs controls the DC current as well as the peak dynamic current of the VCO. Flicker noise in M1 and M2 is modeled as a fluctuating offset voltage that unbalances the differential pair. Balance will be restored by decoupling the sources of M1 and M2 with a capacitor Cc. The P-MOSFET used in the cross-connected pair helps to reduce phase noise due to less flicker noise. This designed mainly used to consume power less than 1 mW .It also provides best FOM.

5.2. Complementary cross coupled LC tank VCO

In [2] 'Complementary cross coupled VCO 'architecture is used .Comparison is made between PMOS current mirror and NMOS current mirror and conclusion is reached on how the tail current affects the whole performance of VCO. In analysis of phase noise and VCO gain factor,it is seen that PMOS current mirror has better performance than NMOS does . PMOS current bias gets lower phase noise and with no more power consumption. This is used to compensate active power loss in LC Tank, also it provide high tuning range.

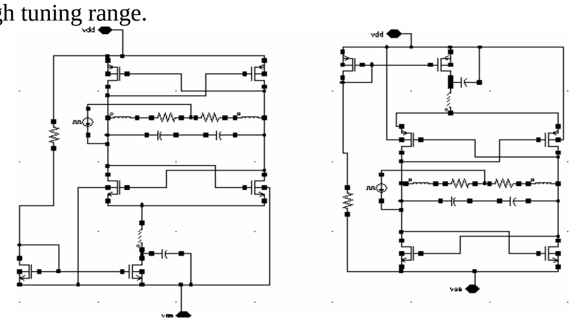

Figure 6: Topologies of VCO

5.3. Cross coupled with pseudo resistance LC tank VCO

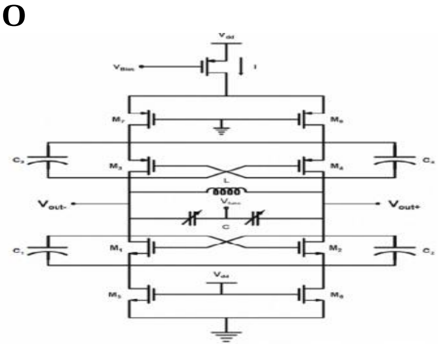

Figure 7:Cross coupled VCO with Pseudo Resistance

A fully differential topology based VCO [3] that uses the technique of added negative transconductance in order to increase the quality factor of the LC tank, improve the phase noise of the VCO .The common mode double pseudo resistance technique used to achieve low power consumption without decrease the phase noise. This is used to consume low current, also it provide best FOM.

5.4. Quadrature VCO with reconfigurable LC tank

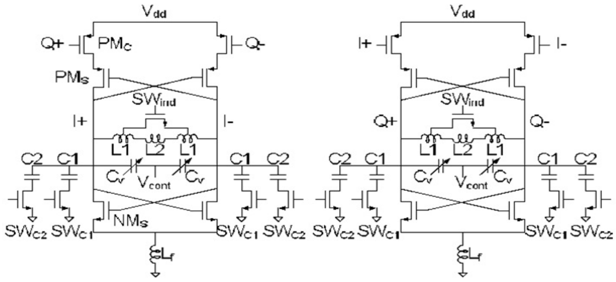

Figure 8:Quadrature VCO with reconfigurable LC tank

Dual band Quadrature VCO with Reconfigurable LC tank design [4] uses series coupled QVCO instead of parallel coupled QVCO because the size of coupling transistors can be increased to acquire better phase accuracy without increasing much current consumption. Current source is excluded to reduce flicker noise from current source. To obtain phase noise performance the filter inductors Lf are connected at the common source node. It is used in a multi standard and multi band transceiver; also it is used for lower current consumption.

6. PROPOSED METHOD

The proposed method for designing the high performance LC tank VCO is to design the basic LC tank VCO by using the above four architectures.Then after performing the simulation,verify the results of each one then compare the results as well as analys each parameter.After analysing each parameter, modification should be done in selected architecture for getting the resultant output.After that verify and at last comparision of result of hybrid model will be done with given four architectures .

7. COMPARISON AND DISCUSSION

From the comparison table, we note that as the value of supply voltage decreases, power consumption also decrease but it provides lower tuning range. And it also provides lower phase noise and best FOM.The Quadrature VCO consumes most of the power but it provides better phase noise as well as FOM for multi band transceiver system.

Table.1.

Mode	**Ref.1**	**Ref.2**	**Ref.3**	**Ref.4**
Technology	0.18	0.18	0.18	0.18
Carrier Freq.	2.4GHz	2.4GHz	2.55GHz	1.80-2.06GHz(LFB) 4.12-4.89GHz(HFB)
Current consume	--	--	1.27mA	4mA
Supply voltage	1.2V	3.3V	1.5V	1.7V
Power consume	0.675mW	--	1.9mW	8.6mW
Tuning range	2.28-2.47GHZ (8%)	2.17-2.70GHz (21%)	2,28-2.59GHz (12.2%)	--
Phase noise	-121.11dBc/Hz @1MHz	<-119dBc/Hz @600K	-125.5dBc/Hz @1MHz	-115.06dBc/Hz @1MHz
FOM	-190.31	--	-190.84	-181.8dB(LFB) -180.5dB(HFB)

8. CONCLUSION

Low phase noise and low power LC tank VCO has been compared by using above four different architectures .But by using these architectures; it is unable to get required value of parameters to reduce the start up time of RF transmitter. Hence we have to design hybrid model to achieve the proposed parameters.

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