CMOS ACTIVE INDUCTOR FOR RF APPLICATION: REVIEW

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Abstract
The performance of RF front-end mainly relies on the performance of the individual RF blocks. The frequency synthesizer is used to generate the multiple numbers of frequencies from a reference frequency. The voltage controlled oscillator is most pertinent block of frequency synthesizer. Due to the passive component like inductor, LC resonator based VCO consumes more die area. This review paper presents the performance of CMOS active inductor over passive inductor in the application of RF voltage controlled oscillator.
Index Terms: Frequency synthesizer (FS), Voltage Controlled Oscillator (VCO)

I. INTRODUCTION

As technology grows up, chip size for wireless communication standards are continuously shrinking.
The miniaturisation of RF transceiver plays a vital role to design the compact wireless devices. In a RF integrated system, design of frequency synthesizer represents a major challenge since the circuit has to meet stringent requirements.

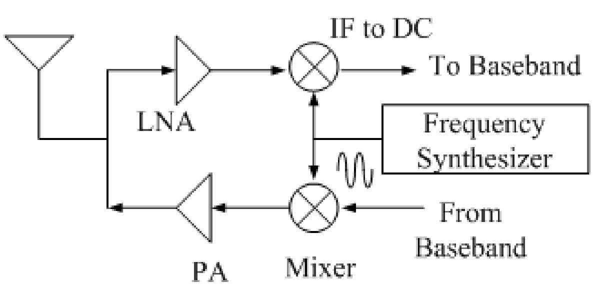

Fig. 1 The role of a frequency synthesizer in a communication transceiver [1]

A frequency synthesizer is a device capable of generating a set of signals of given output frequency with very high accuracy and precision from a single reference frequency. The signal generated at the output of the frequency synthesizer is commonly known as local oscillator signal, since it is used in communication systems as the reference oscillator for frequency translation as shown in Fig 1. The reference signal at high frequency is used to down convert the incoming signal into a lower frequency where it can be processed to extract the information it is carrying. The same reference signal can be used to up convert a desired message to an RF frequency, such that it can be transmitted over the medium.

II. PLL BASED FREQUENCY SYNTHESIZER

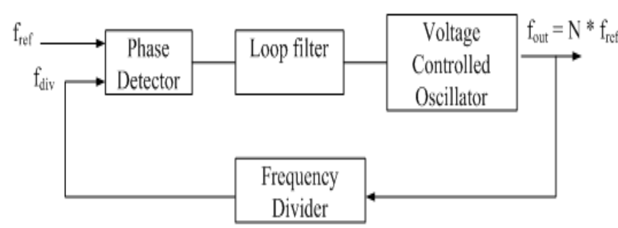

Fig. 2: Basic structure of a phase-locked loop [2]

The PLL based frequency synthesizer is the most widely used frequency synthesizer approach in modern wireless communications systems as shown in Fig 2.
A PLL is a feedback system which minimizes the phase difference between the reference input f_{ref} and the feedback signal f_{div}. Here, a phase detector generates a phase error whose DC value is proportional to the difference between the phases of the reference and feedback signals.

The low pass fillter extracts the DC value and applies it to the voltage controlled oscillator, which changes the output frequency f_{out}. Since frequency synthesizer is required to produce a programmable output frequency, a frequency divider of programmable division ratio N is employed in the feedback path to divide the VCO output frequency to the one comparable to the input reference frequency. When the loop reaches steady state, the phase difference between the reference input f_{ref} and feedback signal f_{div} is constant over time and the relation $f_{out} = N f_{ref}$ holds true. By changing the value of N, the VCO output frequency can be changed.

III. VOLTAGE CONTROLLED OSCILLATOR

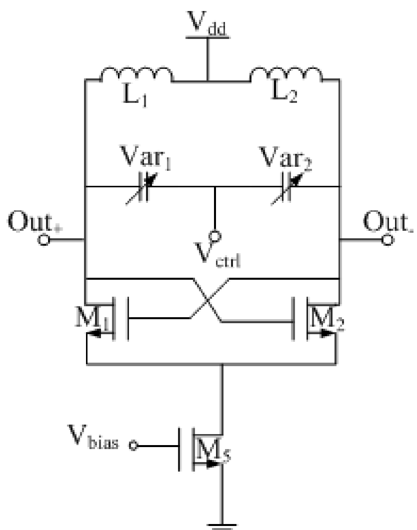

Fig. 3: Schematic of an LC VCO [3]

Fig 3 shows the conventional LC based VCO circuit design. Inductors (L_1 and L_2) and variable capacitors (V_{ar1} and V_{ar2}) form LC tank circuit whereas cross coupled pair (M_1 and M_2) forms negative resistance.

There are various LC based VCO configurations. Mainly it includes NMOS-only, PMOS-only and complementary cross-coupled structures. For the low supply voltage NMOS only and PMOS only are used whereas complementary cross coupled structure improves the phase noise performance [4].

The oscillation frequency of LC topology is given as,

$$\omega = \frac{1}{\sqrt{LC}} \quad (1)$$

Oscillating frequency of the LC based VCO depends upon the inductance and capacitance inversely, thus frequency of oscillation is increased by decrease in inductance and capacitance value [5].

The variation in L and C are responsible for fine and course tuning of LC VCO. Theoretically, the VCO tuning range is determined by the maximum- to-minimum capacitance ratio of the varactor. For a typical capacitance ratio in a standard CMOS process, the tuning range of a LC-tank VCO is approximately limited within 30 %, making it unattractive for wideband applications [6]. To boom the VCO operating frequency range, alternative tuning mechanism is required. As an alternative tuning mechanism tunable active inductor is discussed in this paper.

III. REALISATION OF ACTIVE INDUCTOR

There are two fundamental approaches to realizing an active inductor using only capacitors and active gain elements. One is an operational-amplifier (op- amp) method, which can be used to design active inductors operating at moderate frequencies (up to about 100 MHZ), because of the limited band-width and excessive phase shift of the op-amps.

The other approach that employs a gyrator which is the method used by almost all active inductors operating at gigahertz frequencies [7].

Gyrator

A gyrator consists of two back to back connected trans conductors (voltage to current converters). When one port of gyrator is connected to a capacitor, the network is called as gyrator-C network[8]. Fig 4 and 5 show the single ended active inductor connected to ground and supply voltage respectively.

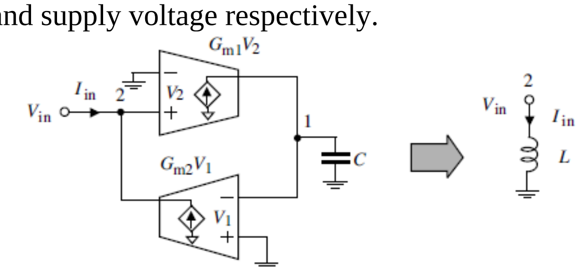

Fig.4 Lossless single ended gyrator-C active inductor connected to ground [9]

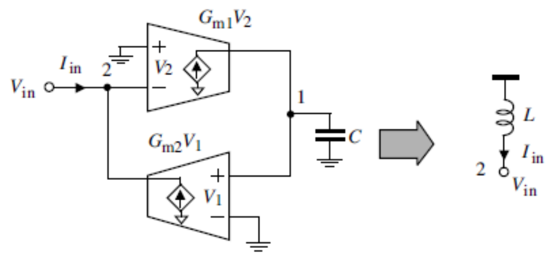

Fig.5 Lossless single ended gyrator-C active inductor connected to supply voltage [9]

To analyse gyrator-C as equivalent inductor, KCL at input port is applied. The simplified form can be explained as,

$$Z_{in} = \frac{sC}{G_{m1}G_{m2}} \quad (2)$$

The coefficient of laplace operator s shows inductance,

$$L = \frac{C}{G_{m1}G_{m2}} \quad (3)$$

In above equation input impedance Z_{in} is directly proportional to frequency, hence the impedance seen at the port 2 is inductive. This is an important property of the gyrator, which enable to synthesize an inductor.

The transistor based active inductor is devel oped using two trans conductors Gm1 (positive) and -Gm2(negative) connected back to back in a negative feedback configuration. The topology is capable of transforming the intrinsic (parasitic) capacitance of a trans conductor to an inductance.

Although the trans conductors of Gyrator-C networks can be configured in various ways, the constraints are that the synthesized inductors should have a large frequency range, low power consumption, small silicon area and the trans conductors are to be configured as simple as possible.

Single ended and differential configured active inductors can be designed by choosing the transconductance amplifier. Common source transconductator is used for single ended negative transconductance whereas common gate and common drain are used for single ended positive trans conductance amplifier. To use floating inductor in LC VCO, differential configuration is widely used.

For spiral inductors, the quality factor of these inductors is independent of the voltage /current of the inductors. This property, however, does not hold for active inductors as the inductance of these inductors depends upon the transconductances of the trans conductors constituting the active inductors and the load capacitance. The variation of the quality factor due to the tuning of L must therefore be compensated for such that L and Q are tuned in a truly independent fashion.

Employment of CMOS active inductor in LCVCO results in number of advantages such as small die area and wide tuning range. Apart from that is also shows some disadvantages like noise due to active components, nonlinearity. VCO important parameters are as tuning range, quality factor, phase noise, output power, frequency pushing, frequency pulling, and linearity. To enhance these parameters number of trans conductance amplifier topologies can be used [10-13].

IV.CONCLUSION

Inception of CMOS active inductor in LC VCO results in number of advantages as compactness, tunability and wide tuning range. It also can be used to design various RF applications as low noise amplifier, power amplifier/combiner, RF filters etc. The selection of appropriate trans conductance amplifier in gyrator topology can meet the stringent parameters for RF application.

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