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Active Inductor based VCO for High Tuning Range

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ABSTRACT
This paper presents a study of Active inductor based VCOs that helps in increasing the tuning range of the VCO , reduces the chip size and phase noise of the circuit. Study has been done on LC VCOs by replacing the passive inductors with the active one consisting of MOSFET. Design of circuit has been done on Orcade Capture using .18um technology.power consumption of circuit is 1.33mW with tuning range of 81**%.**Tuning range of the VCO is increased because the active inductor cancels out the parasitic capacitance of the circuit.

Keywords
Active inductor, LC Oscillator, VCO, RF circuit.

1. INTRODUCTION
The ever increase in the growth of wireless communication market and their use in multimedia applications keeps pushing the CMOS integrated wireless circuits to work for high speed, low cost analog signal processing and data communications.

Voltage controlled oscillators (VCO's) are an integral part of RF systems such as frequency synthesizers i.e. Local Oscillators, PLL and clock recovery circuits. For high frequency applications we need circuits with less fluctuations and low phase noise as they have a direct impact on the tuning accuracy of the circuit. Several mechanisms exist to tune the oscillation frequency of LC- tank oscillators i) tuning the capacitance of Varactor, ii) tuning the inductance of Inductor. Tuning the capacitance does not provide large tuning range, but its not suitable to use passive inductor in ICs hence large frequency tuning range is obtained by varying the inductance of the active inductor , using active inductors in place of spiral passive inductors reduces the silicon consumption of the oscillator, cost and phase noise performance is also increased.

2. Active Inductor
As it is not suitable to implement passive inductor in an integrated circuit hence active devices are used to built inductors called active Inductors. Active devices like MOSFETs are used to design Active Inductors that offers the advantage of a tunable inductance and small silicon area.

2.1 Gyrator-C floating Active Inductors
Gyrator consist of two voltage controlled current sources (transconductors) connected back to back [2], one port of the gyrator is terminated with a capacitive load and an inductive characteristic at the other port as shown in fig.1.Assuming infinite input impedance , the admittance at port 1 of gyrator will be:

$$Y(S) = sC_S G_{02} + \frac{1}{s\left(\frac{C_1}{g_{m1}g_{m2}}\right) + \frac{G_{01}}{g_{m1}g_{m2}}} \dots\dots\dots\dots (1)$$

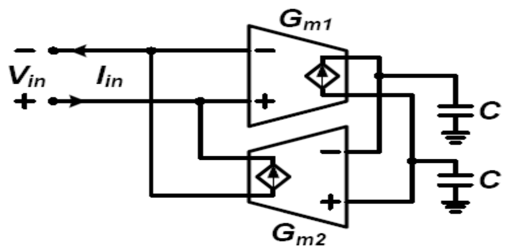

Fig 1: Floating Gyrator C Active Inductor.

Eq. (1) can be represented by an equivalent RLC circuit

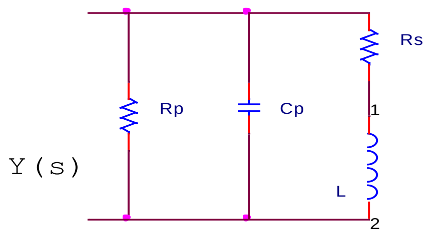

Fig 2: RLC Equivalent Of Gyrator C Active Inductor.

With

$$L_{eq} = \frac{C_{PAR}}{gm1\ gm2} \dots\dots (2)$$

The inductance can be tuned by varying gm_1 and gm_2.

3. PROPOSED ACTIVE INDUCTOR

The Proposed active inductor shown in fig.3 is based on gyrator –C floating structure [3], [6]

3.1 How noise is controlled

When the magnitude of common mode signal increases due to noise or any other interference signals, the source nodes of common drain configured transistors M5 and M6 increases too. So gate voltage of M3, M1 goes high which leads to lower magnitude of common mode signal in "a" and "b". and therefore terminal nodes.

3.2 How tuning range is controlled

Tuning range i.e. frequency of oscillation is increased through control voltage Vcnt at gate of M2 and M4. Increasing Vcnt leads to lower voltage in gates of M3 and M1 and so increases their currents. So the transconductance of M8 and M9 increases and as inductance is inversely proportional to transconductance it decreases leading to a higher oscillation frequency.

3.3 Application of Proposed Active Inductor in VCO

The proposed active inductor is applied to realize tunable inductance controlled VCO. It has a wider tuning range of inductance as compared to a varactor tuning VCO.

Table 1. Performance Comparison Of Different Active Inductor Based VCO

work	Power supply (V)	Tuning range	P_{dc}	Technology used
1	2.5	31.4%	10mW	.25um
2	3.3	84%	>10mW	.35um
3	1.8	76%	2.23mW	.18um
This work	1.8	81%	1.33mW	.18um

3.4 Simulation results

Transconductance

$$gm = \sqrt{2u_o}C_{ox}\frac{W}{L} * I_d$$

Transconductance of M8 and M9 increases as their drain current increases.

Inductance of circuit

$$L_{eq} = \frac{C_{PAR}}{gm1\ gm2}$$

As inductance is inversely proportional to the transconductance, thus when transconductance of M8 and M9 increases (section 3.2) Inductance of the circuit decreases.

Oscillation frequency

$$F = \frac{1}{\sqrt{L_{eq}C_{eq}}}$$

Also oscillating frequency of the VCO depends upon the Inductance inversely, thus frequency of oscillation is increased by decrease in inductance value.

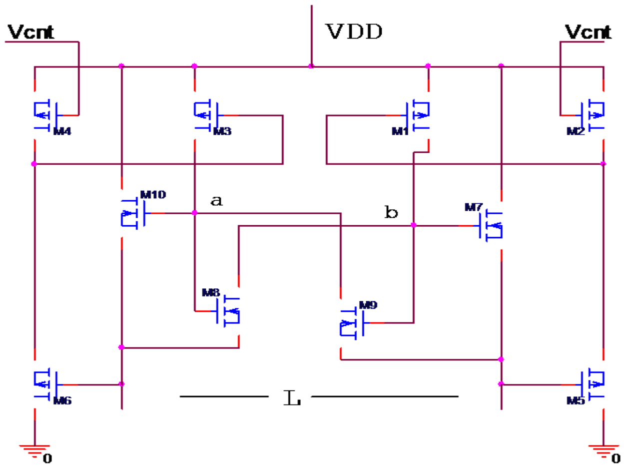

Fig 3 (a): Proposed Active Inductor

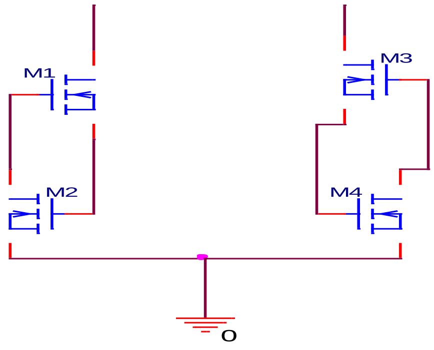

Fig 3 (b): Circuit for negative resistance

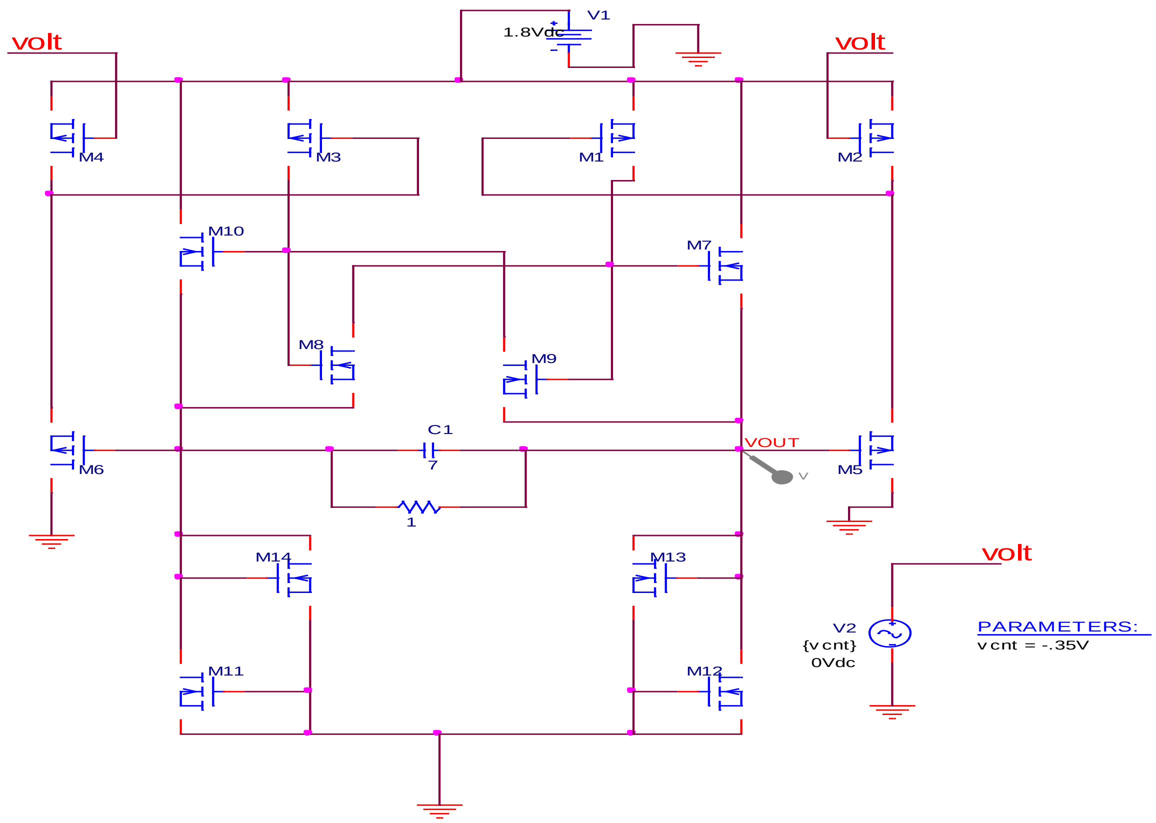

Fig 4: Implementation Of Proposed Inductor In Vco Circuit.

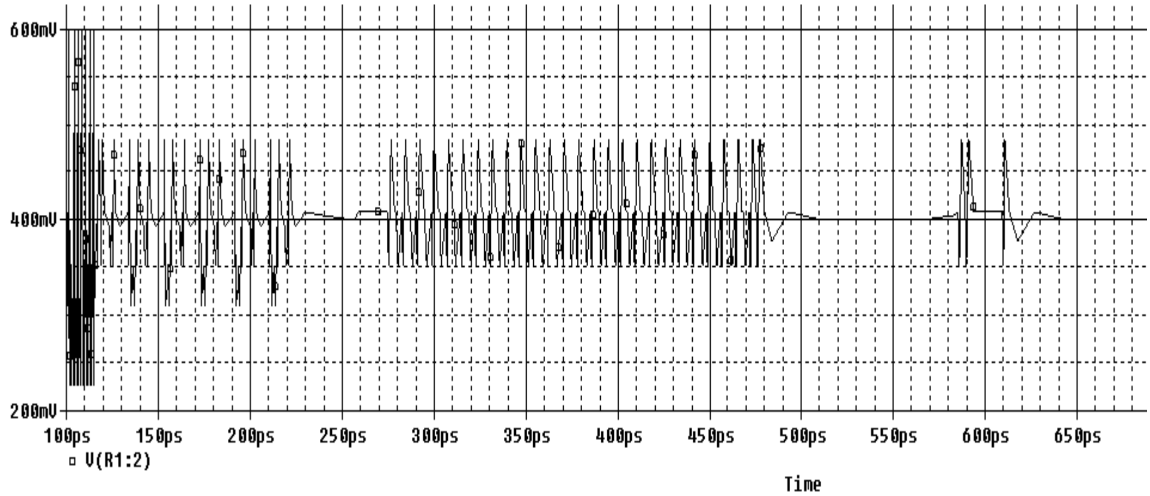

Fig 5: Oscillating Output Of The VCO

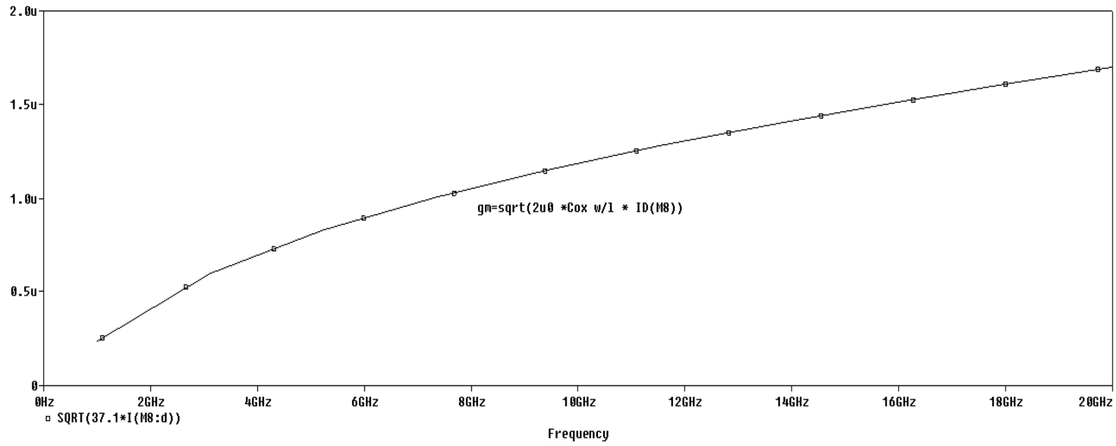

Fig 6: Transconductance Vs Operating Frequency

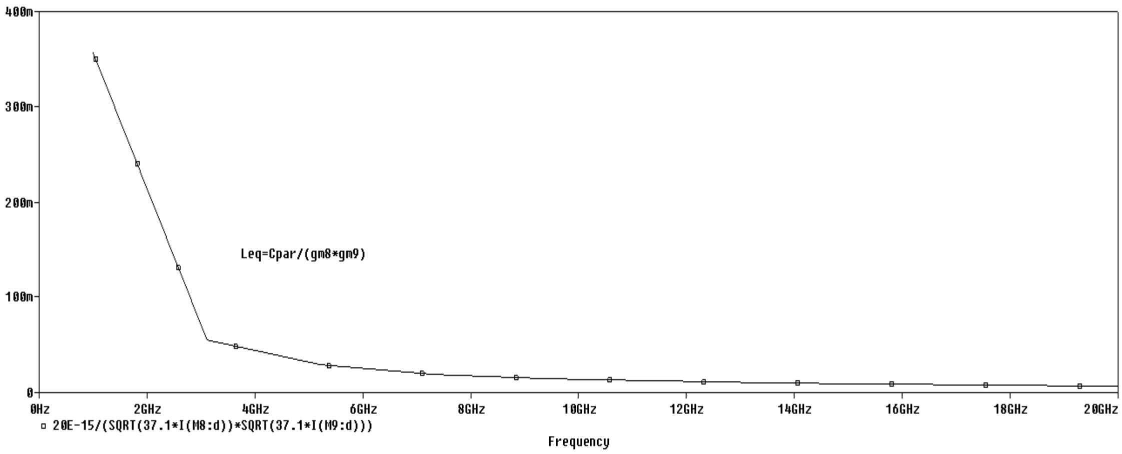

Fig 7: Inductance Vs Operating frequency

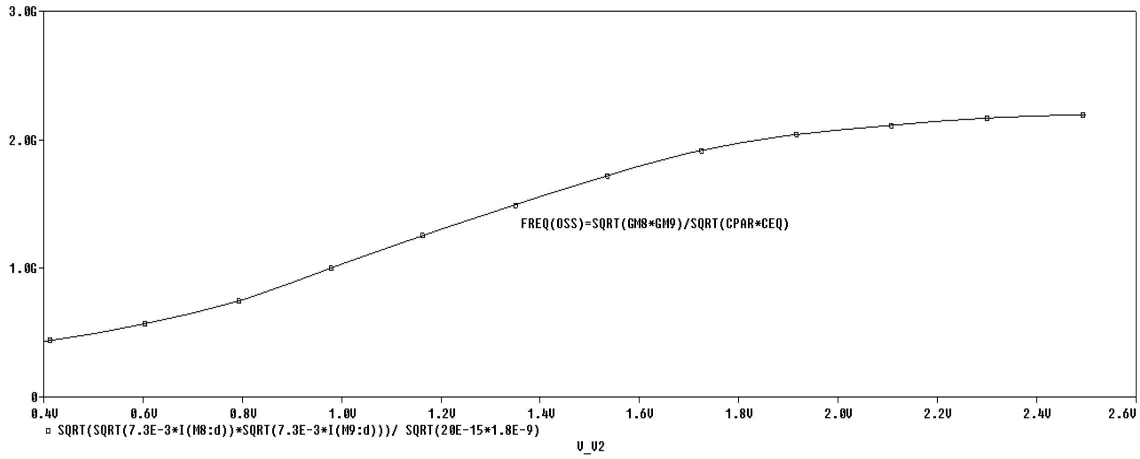

Fig 8: Oscillating Frequency Vs Control Voltag

4. Conclusion

This paper has shown that Active Inductor based LC VCO are both capable of low power and high tuning range. The analysis developed in this work and measurement results taken on prototypes has shown that it works fine for high tuning range application.

5. ACKNOWLEDGMENTS

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