

Multiple circuit topologies of VCO's for Multi-Standard applications

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Abstract—This paper presents a novel circuit topology of the Switched capacitor voltage controlled oscillator, conventional LC tank VCO and active inductor VCO for Multi-standard applications. Recent advances in wireless communication market, a wireless device should be compatible with the standards of personal area network, cellular networks and WLAN. Multi standard VCO is used in receiver section to tune wide range of frequency with input control signal. Switched capacitor circuits are used to operate circuit in discrete time periods, VCO constructed using switched capacitor can attain low power consumption. The work proposes the design of all three VCO's and compares result between them. Simulation is done in Spice tools . Cosmoscope .

Keywords—Switch Capacitor VCO ,Conventional LC tank VCO, Active inductor VCO,FM Modulator.

I. INTRODUCTION

A voltage-controlled oscillator or VCO is an electronic oscillator designed to be controlled in oscillation frequency by a voltage input. The frequency of oscillation is varied by the applied DC voltage, while modulating signals may also be fed into the VCO to cause frequency modulation (FM) or phase modulation (PM); a VCO with digital pulse output may similarly have its repetition rate (FSK, PSK) or pulse width modulated (PWM).

1.1 TYPES OF VCO's:

VCOs can be generally categorized into two groups based on the type of waveform produced: 1) harmonic oscillators, and 2) relaxation oscillators. Harmonic oscillators generate a sinusoidal waveform. They consist of an amplifier that provides adequate gain and a resonant circuit that feeds back signal to the input. Oscillation occurs at the resonant frequency where a positive gain arises around the loop. Some examples of harmonic oscillators are crystal oscillators and LC-tank oscillators. When part of the resonant circuit's capacitance is provided by a varactor diode, the voltage applied to that diode varies the frequency.

Relaxation oscillator VCOs can have three topologies: 1) grounded-capacitor VCOs, 2) emitter-coupled VCOs, and 3) delay-based ring VCOs. The first two of these types operate similarly. The amount of time in each state depends on the time for a current to charge or discharge a capacitor. The delay-based ring VCO operates somewhat differently however. For this type, the gain stages are connected in a ring. The output frequency is then a function of the delay in each of stages.

Harmonic oscillator VCOs has these advantages over relaxation oscillators.

- Frequency stability with respect to temperature, noise, and power supply is much better for harmonic oscillator VCOs.
- They have good accuracy for frequency control since a crystal or tank circuit controls the frequency.

A disadvantage of harmonic oscillator VCOs is that they cannot be easily implemented in monolithic ICs. Relaxation oscillator VCOs are better suited for this technology. Relaxation VCOs are also tuneable over a wider range of frequencies.

II. CONTROL OF FREQUENCY IN VCOS

A voltage-controlled capacitor is one method of making an LC oscillator vary its frequency in response to a control voltage. Any reverse-biased semiconductor diode displays a measure of voltage-dependent capacitance and can be used to change the frequency of an oscillator by varying a control voltage applied to the diode. Special-purpose variable capacitance varactor diodes are available with well-characterized wide-ranging values of capacitance. Such devices are very convenient in the manufacture of voltage-controlled oscillators. For low-frequency VCOs, other methods of varying the frequency (such as altering the charging rate of a capacitor by means of a voltage controlled current source) are used. See Function generator.

2.1 Applications:

VCOs are also used in:

Electronic jamming equipment, generators, The production of electronic music, to generate variables, Phase, Frequency used in communication equipment.

III. BACK GROUND

3.1 A Wideband Receiver

INTENSE research activity toward the realization of mm-wave integrated systems has been carried out in the recent past. Transceivers for high rate wireless video download are expected to be pervasive in consumer products, taking advantage of low-cost, compact solutions offered by CMOS technologies. High performance analog blocks and processing chains achieving adequate dynamic range have been published and successful demonstrations of Gb/s communications have been reported.

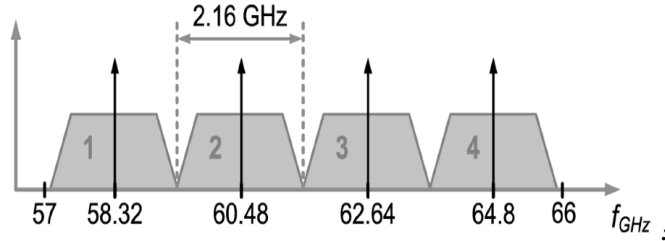


Fig 3.1 Spectrum allocation

One key aspect of the transceiver is the ability to handle wide analog bandwidths, challenging for both the linear processing chain and the frequency reference generator. According to international regulations, dedicated channels are 2.16 GHz wide and occupy the frequency range between 57.2 GHz and 65.8 GHz, as shown in Fig. 3.1. The corresponding RF fractional bandwidth is 14%, mandating an analog front-end fractional bandwidth in excess of 20% considering spreads due to process variations. At mm-wave frequencies, gain is rare discouraging trading gain for bandwidth.

In this work, which extends, we exploit a higher order filter at the inter-stage between front-end blocks with significant improvement of the gain-bandwidth product at the expense of a moderate in-band ripple. This technique has been applied to both LNA and mixer, resulting in an extremely sensitive 65 nm CMOS receiver with noise figure (NF) 6.5 dB over 13 GHz bandwidth, verified with experiments on realized prototypes.

The receiver, adopts a sliding IF architecture preferred to a direct conversion because it does not require a quadrature high frequency oscillator and to a fixed IF due to a more relaxed synthesizer frequency range requirement. The synthesized local oscillator (LO) frequency and the intermediate frequency (IF) are set to 2/3 and 1/3 the received frequency, respectively.

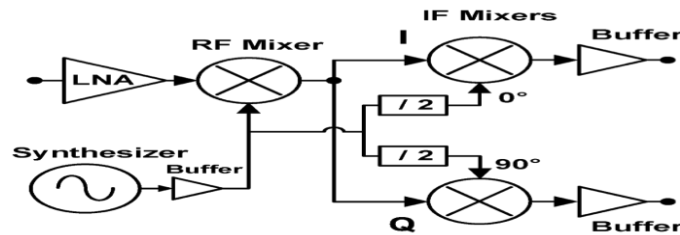


Fig 3.2: Integrated receiver

3.2 Double-Driven Coupled Resonators

THE wireless scenario for mobile and portable communications is rapidly changing from single standard systems to multi-mode terminals, with attention geared towards software defined radios and cognitive radios. Cognitive radio (CR) has recently emerged as an umbrella term for systems that can adapt to changing conditions so as to dynamically use the spectrum in an opportunistic manner. The adaptation/reconfigurability functions will be handled by adaptive frequency-agile RF transceivers, which are viewed as the foundation of CR in its most extreme form of a radio that can jump in and out of any band and any operating mode.

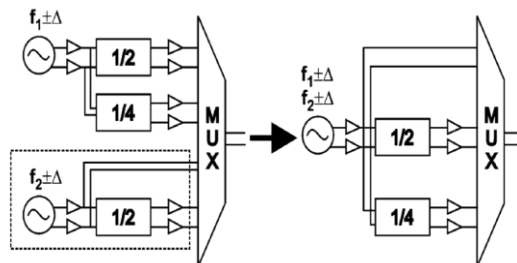


Fig 3.3: Multi-band generation architecture

- (a) Typical multi-band frequency generation architecture.
- (b) Reduction

A number of local-oscillator (LO) frequencies are typically needed to cover such a wide spectrum. Since oscillators consume a substantial part of the chip area and battery power, methods to generate multiple LO frequencies in a

compact design can be very effective for power and area savings. In many radio architectures, particularly in multi-mode and multi-band systems, the required local-oscillator frequencies are not necessarily harmonically related. Thus, the main focus of the research so far has been on offering multi-band frequency generators based on local oscillators with additional processing through frequency division, frequency up-/down-conversion, and multiplexing functions Fig 3.3. The tuning range of each individual local oscillator determines their total number and the required additional frequency processing circuitry..

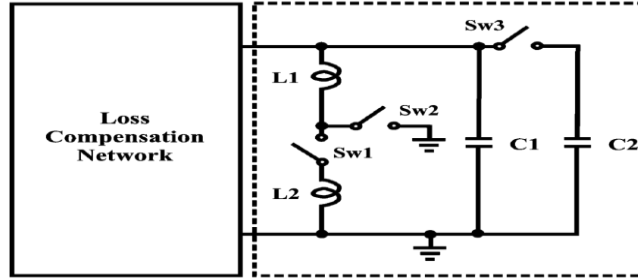


Fig 3.4: Switched capacitor

This paper details the concept of coupled driven resonators and applies it to the design of a CMOS VCO that is capable of operating in two widely separated bands, while simultaneously achieving wide tuning range in each band. The relation between the coupling coefficient of the transformer load, selection of frequency bands, and the resulting quality factor at each band is investigated. This approach would allow hardware sharing of the divider and mixing functions that would ultimately decrease the power and area consumptions relative to traditional

Operation techniques.: It can also provide lower current consumption compared to continuous magnetic tuning of transformer loads by utilizing varactor tuning within each band and injecting current in the secondary winding only when switching from one frequency range to the other.

3.5 Low-Voltage VCO

DUE TO the explosive growth of low-cost mobile wireless handheld devices, power consumption has become one of the most important design criteria in digital, analog, and RF circuits. To reduce the power consumption of a system, low-voltage operation has been a popular method, especially for digital circuits where supply voltage has been lowered below the threshold voltage. In analog and RF circuits, low-voltage operation is difficult to achieve due to the reduced signal-to-noise ratio (SNR). Nevertheless, the increasing demand for low power consumption in wireless communication systems requires low-voltage operation for analog and RF circuits as well. Hence, circuit designers have recently been trying to lower the supply voltage of analog and RF circuits.

In RF circuits, there have been active researches for low-power low-voltage voltage-controlled oscillators (VCOs). Although they achieve low phase noise and low power consumption, their limited tuning range makes them impractical for use in practical systems. While there are several ways to extend the tuning range such as tank optimization and a switched tuning scheme, they are not appropriate for low-voltage VCOs.

For example, reducing the inductance and increasing the varactor of a tank can increase the tuning range. However, this technique brings about low impedance, which, in turn, leads to difficult startup conditions and high power consumption.

The problem of a low-voltage VCO, which hinders its practical usage, is its high sensitivity to process, voltage, and temperature (PVT) variations as caused by the exponential property of CMOS in the sub-threshold region. To guarantee stable operation over PVT variations, the VCO is typically designed for the worst case, which leads to high power consumption. To reduce the power consumption, a VCO that is immune to PVT variations must be designed.

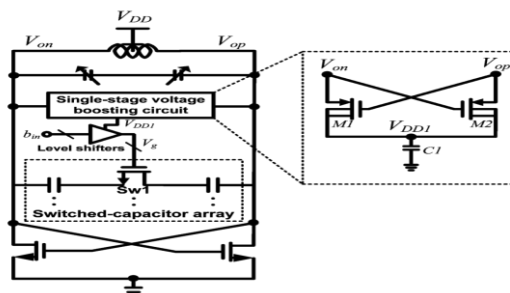


Fig 3.5: Switch capacitor bank

In this paper, a 0.5-V CMOS VCO with a wide tuning range and low sensitivity to PVT variations is presented in the 0.18- m process. To alleviate the tradeoff between the tuning range and the phase noise in the switched tuning scheme, a multistage voltage-boosting circuit is proposed, which is superior to an earlier voltage-boosting circuit proposed by the authors. In addition, to alleviate the need for the worst-case design and increase the VCO's robustness to PVT variations, an adaptive body-biasing technique is proposed. Unlike an earlier study in which only simulation results of the adaptive body-biasing technique are shown, this paper provides extensive experimental results that verify its performance.

IV. PROPOSED WORK

4.1: Conventional LC Tank VCO:

LC VCOs have the advantage of large transistor voltage swings and low phase noise. However, their power dissipation is excessive. At lower frequencies, CMOS VCOs have gained popularity due to their low power dissipation brought about by the significantly lower supply voltages. However, to date, CMOS VCOs suffer from inadequate output power levels, reduced tuning range and, until recently, from very poor phase noise. Here, a family of 90-nm CMOS VCOs with record tuning range and phase noise performance at 3GHz is presented.

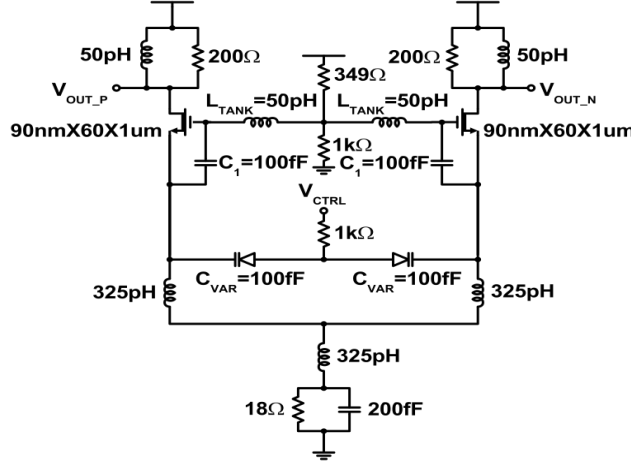


Fig 4.1 LC tank VCO

In cross-coupled VCOs, as the parasitic capacitances of transistors are directly lumped to the tank capacitance, the tuning range is limited by the transistor size. The output buffer further degrades it, which is always present in cross-coupled VCOs, either to drive the 50-Ω test equipment or to distribute the VCO signal to mixers and frequency dividers in an IC. At mm-wave frequencies, where a relatively large transistor size has to be used to maintain oscillation, tuning range is sacrificed. At lower frequencies, large tuning range can be realized with small transistor and large varactor sizes which also leads to lower power dissipation, and thus to a superior figure of merit. However, for the same reasons, its output power is generally far below the acceptable range of 0 to 5 dBm. By comparison, the Colpitts VCO requires larger transistor size and current to produce the oscillation, and hence dissipates more power.

4.1.1 THEORITICAL DERIVATIONS:

$$f_{osc} = \frac{1}{2\pi\sqrt{L_{TANK}C_{eq}}}$$

$$C_{eq} = \frac{(C_1 + C_{GS})(C_{VAR} + C_{SB})}{C_1 + C_{VAR} + C_{GS} + C_{SB}} + C_{GD} \approx \frac{C_1 C_{VAR}}{C_1 + C_{VAR}}$$

$$G_m \geq \omega_{osc}^2 C_1 C_{VAR} R_S$$

$$R_S = \frac{\omega_{osc} L_{TANK}}{Q_L}$$

$$C_{eq} = C_{VAR} + C_{GS} + 4C_{GD} + C_{DB} + C_{GS_M1} + C_{GD_M2}$$

$$R_p = \omega_{osc} L_{TANK} Q_L$$

$$L_{TANK}' = \frac{L_{TANK}}{k}, C_1' = \frac{C_1}{k}, C_{VAR}' = \frac{C_{VAR}}{k}$$

$$f_{osc}' = k f_{osc}$$

$$R_S' = \frac{R_S}{k} \quad G_m' = \frac{G_m}{k}$$

An algorithmic design methodology for LC CMOS VCOs has been presented and validated in measurements. Record tuning range has been achieved at 3 GHz using a Colpitts topology, and the first cross-coupled VCO employing p-MOSFETs operated. Power analysis for each value of control voltage is measured.

4.2 Active Inductor CMOS VCO

Active inductor which are constructed using cmos are used in VCO in LC circuits, since inductor are implemented using cmos, area can be reduced drastically, current consumption is also reduced, fabrication in also very easy.

4.2.1 CIRCURIT DIADRAMS:

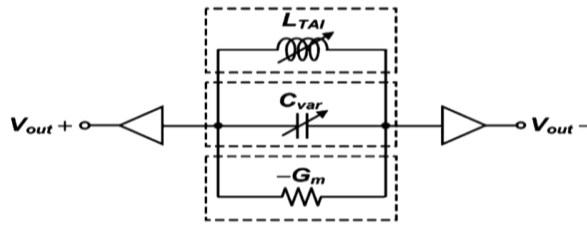


Fig 4.2.1: Conceptual VCO

A conceptual illustration of the proposed VCO, where the LC-tank is composed of a tunable active inductor and a varactor for frequency control, and the negative conductance is employed to compensate for the loss from the LC-tank. Since the equivalent inductance of an active inductor can be tuned over a wide range, it is employed as the mechanism for coarse frequency tuning or band selection. In addition, a varactor is included in the LC-tank for fine tuning, maintaining a relatively low tuning sensitivity to ensure the frequency stability.

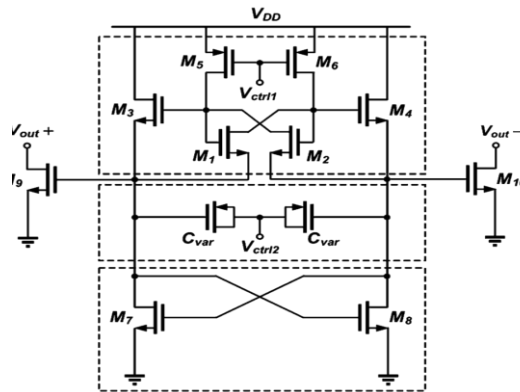


Fig 4.2.2: ACTIVE INDUCTOR VCO CIRCURIT DAIGRAM

The complete schematic of the proposed VCO including all on-chip components is shown in The tuneable active inductor is implemented by transistors, where the gyrator architecture including a gain and a feedback element is adopted to emulate the current–voltage characteristics of an inductor. Instead of using the conventional one-port active inductors, a two-port circuit topology is adopted, allowing fully differential operation of the VCO.

The equivalent inductance of the active inductor is controlled by. By optimizing the maximum-to-minimum inductance ratio of the tunable active inductor, the limitations on VCO tuning range can be alleviated. As a result, a wideband operation with continuous frequency tuning is realized.

Accumulation-mode MOS devices are used as the varactor where the effective capacitance is controlled by. Since the varactor is only for the purpose of fine-tuning, it can be optimized for the required tuning sensitivity without degrading the overall tuning range of the VCO. As for the loss compensation, nMOS cross-coupled transistors are employed to provide the negative conductance. By stacking the cross-coupled pair with the differential active inductor, a current-reuse bias scheme is established to minimize the power consumption.

The circuit is implemented in 180nm technology, there are two control voltages v_{ctrl1} and v_{ctrl2} , where v_{ctrl1} is for tuning inductor value and v_{ctrl2} for oscillator control voltage.

4.3 A Switched-Capacitor VCO

Portable devices are required to operate for extended periods of time without need to charge or change exhausted batteries. This means the importance of low-power circuits on portable systems. Among the building blocks of any transceiver, a voltage-controlled oscillator (VCO) is an important building block. A great deal of research has focused on the LC-tank VCO's consisting of passive inductors, transformers, and varactors, which are available with advancement of CMOS technology.

In this paper, we present a modified topology to reduce influence degree of the device parameters on the circuit performances. In addition, the larger VCO gain (KVCO) brings about the worse phase noise. Hence, the topology of switching capacitor is used to enhance the characteristics of phase noise by dividing the wanted frequency band into four sections.

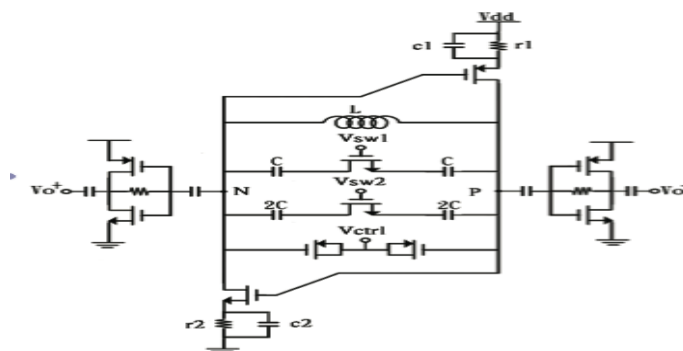


Fig 4.3: circuit diagram of switched capacitor

Fig.4,3 shows the schematic of the presented switching-capacitor current reused VCO. The current-reused LC-VCO consists of cross-connected pair transistors M1 and M2, LC- tank and two switched capacitors. The current-reused VCO must usually be designed carefully to arrive at symmetrically differential output signals.

The equivalent drain capacitance and the Transconductance g_m resulted from the NMOS and PMOS transistors must be balanced in order that the output wave is fully differential. That means that the proper choice of device parameters will result in the symmetrical behaviour of charge and discharge at the two output terminals, and then differential output signals.

V. APPLICATION

5.1: FM - GENERATION BY VCO

A very simple and direct method of generating an FM signal is by the use of a voltage controlled oscillator -VCO. The frequency of such an oscillator can be varied by an amount proportional to the magnitude of an input (control) voltage. Such oscillators, in the form of an integrated circuit, have very linear characteristics over a frequency range which is a significant percentage of the centre frequency.

Despite the above desirable characteristic, the VCO fails in one respect as a generator of FM - the stability of its centre frequency is not acceptable for most communication purpose

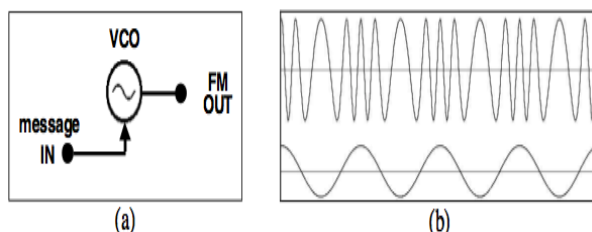


Fig 5.1(a) Block diagram of VCO as FM modulator Fig 5.1(b) FM signal

The above figure shows a snap shot time domain display of an FM signal, together with the message from which it was derived. The frequency change is large compared with the un modulated output frequency, and the carrier frequency is only four times that of the message. So this waveform is not a typical one. But it can be reproduced with TIMS.

Note particularly that there are no amplitude variations - the envelope of an FM waveform is a constant.

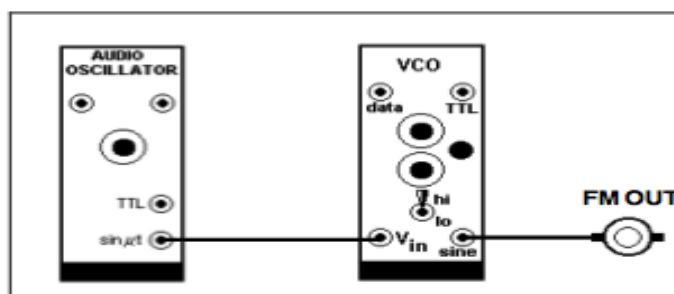


Fig 5.2 FM generation model

A model of the VCO method of generation is shown in Figure 4.1.2. Note that the on-board switch SW2 must be set to 'VCO'.

VI. RESULTS AND DISCUSSIONS

The different types of VCO's are designed and being simulated using the cosmoscope the below wave forms shows the output of VCO's at different voltages as specified clearly.

6.1 CONVENTIONAL LC VCO:

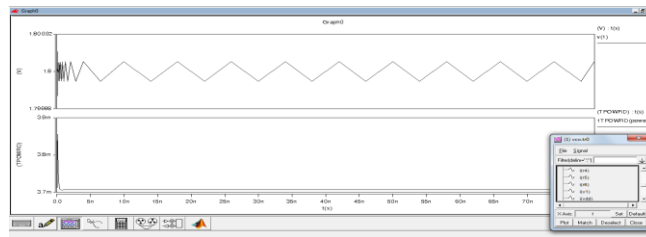


Fig6.1:SIMULATION RESULT AT CONTROVOLTAGE0.5V

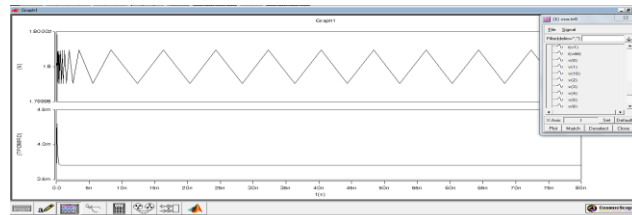


Fig6.2: SIMULATION RESULT AT CONTROL VOLTAGE 1V

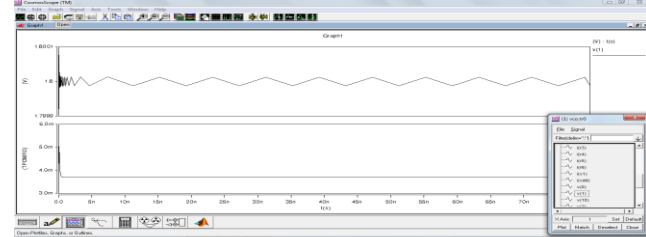


Fig6.3:SIMULATION RESULT AT CONTROL VOLTAGE 1.5V

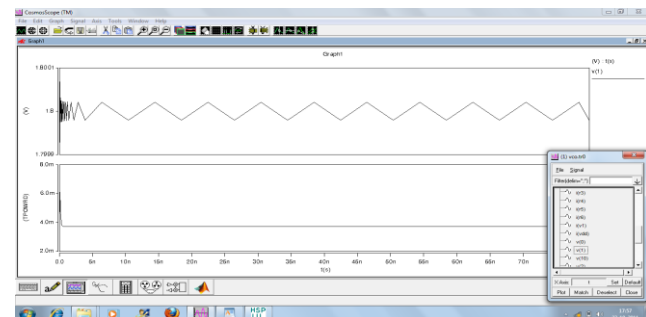


Fig6.4: SIMULATION RESULT AT CONTROL VOLTAGE 2V

6.2 ACTIVE INDUCTOR VCO

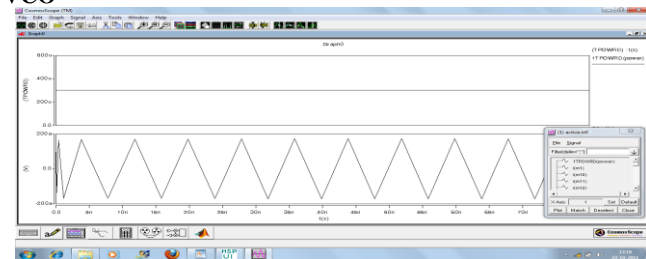


Fig6.5:SIMULATION RESULT AT CONTROVOLTAGE0.5V

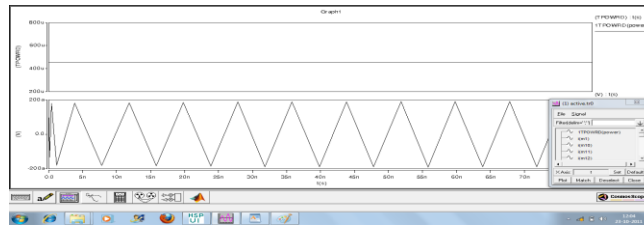


Fig6.6: SIMULATION RESULT AT CONTROL VOLTAGE 4V

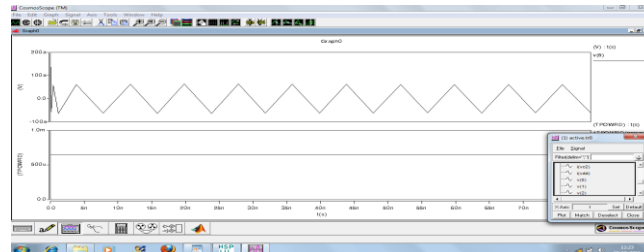


Fig6.7: SIMULATION RESULT AT CONTROL VOLTAGE 1.5V

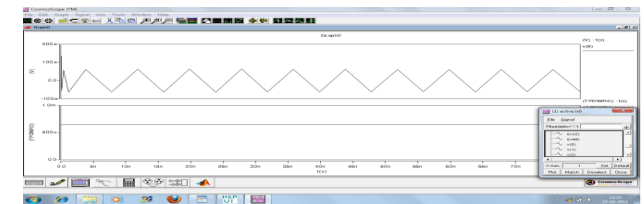


Fig6.8: SIMULATION RESULT AT CONTROL VOLTAGE 2V

6.3 SWITCHED CAPACITOR VCO

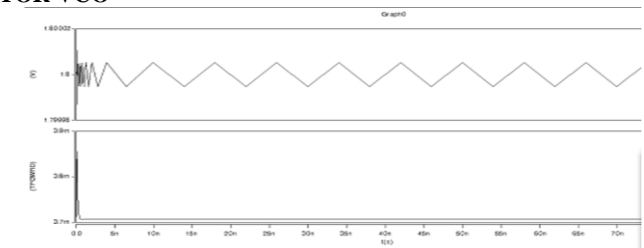


Fig6.9: SIMULATION RESULT AT CONTROL VOLTAGE 0.5V

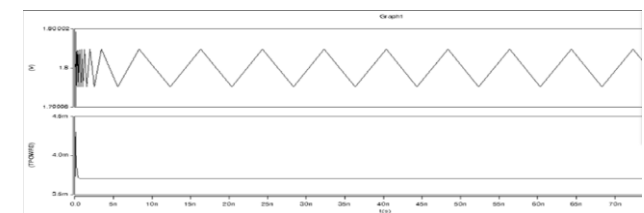


Fig6.10: SIMULATION RESULT AT CONTROL VOLTAGE 1V

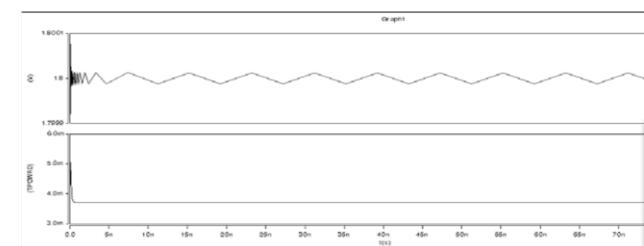


Fig6.11: SIMULATION RESULT AT CONTROL VOLTAGE 1.5V

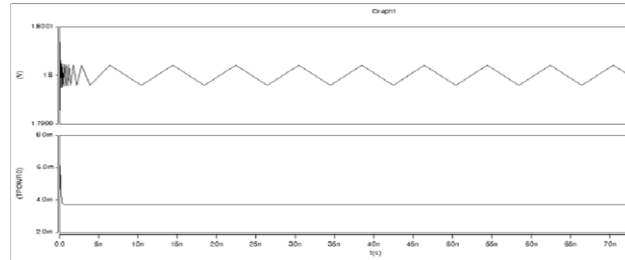


Fig6.12: SIMULATION RESULT AT CONTROL VOLTAGE 2V

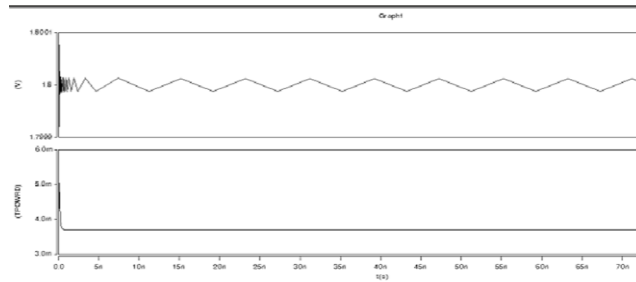


Fig6.13: SIMULATION RESULT AT CONTROL VOLTAGE

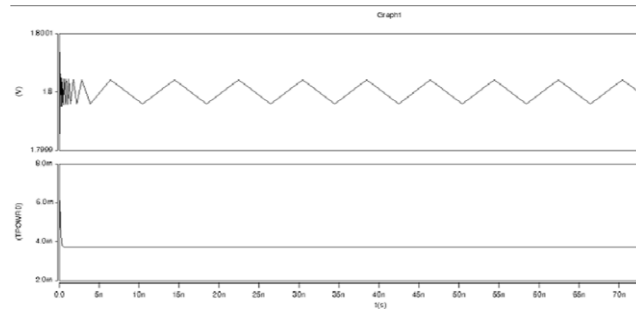


Fig6.14: SIMULATION RESULT AT CONTROL VOLTAGE 3V

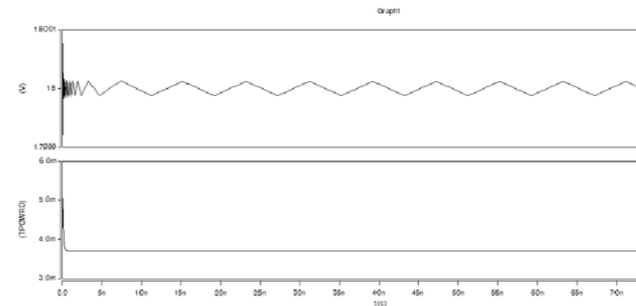


Fig6.15: SIMULATION RESULT AT CONTROL VOLTAGE 3.5V

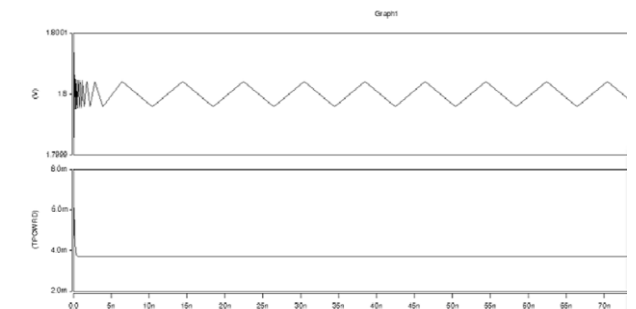


Fig6.16: SIMULATION RESULT AT CONTROL VOLTAGE 4V

6.4 PHASE NOISE ANALYSIS:

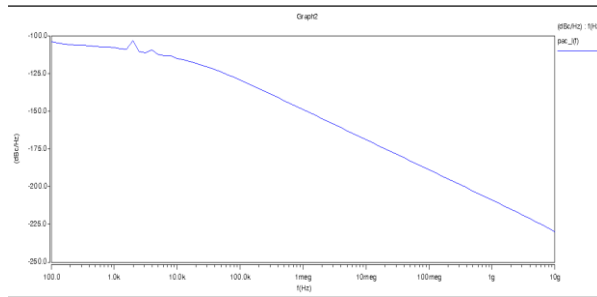


Fig 6.17: SIMULATION RESULT AT CONTROL VOLTAGE 0.5V

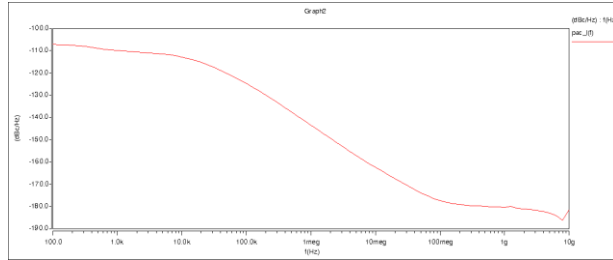


Fig 6.18: PHASE NOSIE OF ACTIVE INDUCTOR VCO

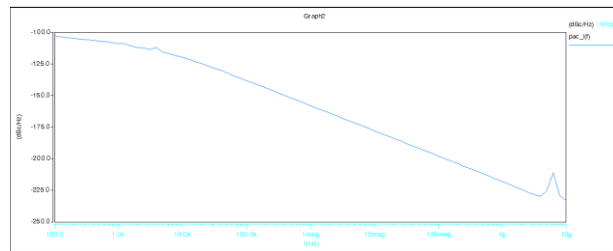


Fig 6.19: PHASE NOSIE OF SWITCHED CAPACITOR VCO

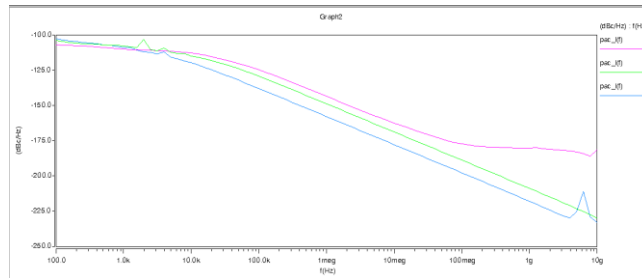


Fig 6.20: COMPARISON OF PHASE NOSIE OF ALL THREE CRICURITS

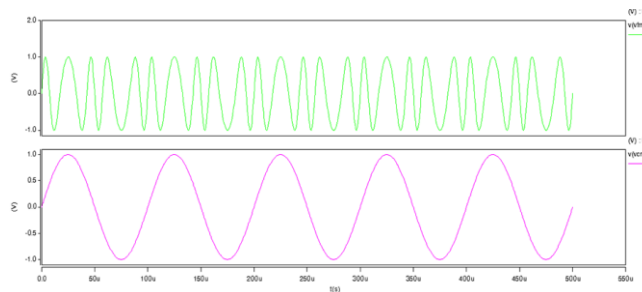


Fig 6.21: SIMULATION RESULTS OF VCO AS FM MODULATOR:

Analysis : LC TANK VCO:

V Cntrl (v)	Frequency (GHZ)	Peak Power (mW)	Average Power (mW)
0.5 V	1.8	3.8	3.77
1.0V	2.2	4.5	3.97
1.5V.	2.8	5.2	4.66
2.0V	3.2	6.1	5.23

Table 6.22: Comparison of parameters in LC Tank VCO

From above circuit we can conclude that power and frequency increase with respect to time, but problem from the above circuit is that it has tuning capability till 3.2 GHz after that frequency doesn't change in big scale. TO more tuning and good power performance active inductor are used in circuit.

ACTIVE INDUCTOR VCO :

V Cntrl (v)	Frequency (GHZ)	Peak Power (mW)	Average Power (mW)
0.5V	2.8	0.36	0.36
1.0V	3.9	0.48	0.48
1.5V.	5.6	0.63	0.63
2.0V	6.2	0.82	0.82

Table 6.23: Comparison of parameters in ACTIVE INDUCTOR VCO

SWITCHED CAPACITOR VCO:

V Cntrl (v)	Frequency (GHZ)	Peak Power (mW)	Average Power (mW)
0.5 V	2.6	0.8	0.75
1.0 V	3.3	1.0	0.89
1.5 V	4.7	1.4	0.98
2.0 V	5.8	1.7	1.42
2.5 V	7.1	2.1	1.88
3.0 V	8.4	2.3	2.0
3.5 V	9.6	2.8	2.63
4.0 V	10.04	3.2	2.97

Table 6.24: Comparison of parameters in switched capacitor VCO

From above results we can tell that tuning of switch capacitor is more than other two circuits.

COMPARSION OF PHASE NOSIE OF ALL THREE VCO'S:

Circuit	Phase Noise
Conventional VCO	-137db at 1mhz
Active Conductor VCO	-122db at 1mhz
Switched Capacitor VCO	-131db at 1mhz

Table 6.25: Comparison of Phase noise in all three VCO's

<i>VTune</i>	<i>Power LC VCO (mW)</i>	<i>Power Active (mW)</i>	<i>Power Switched (mW)</i>	<i>Freq LC VCO (GHz)</i>	<i>Freq Active VCO (GHz)</i>	<i>Freq Switched VCO (GHz)</i>
0.5	3.77	0.36	0.75	1.8	2.8	2.6
1.0	3.97	0.48	0.89	2.2	3.9	3.3
1.5	4.66	0.63	0.98	2.8	5.6	4.7
2.0	5.23	0.82	1.42	3.2	6.2	5.8
2.5	5.38	0.94	1.88	3.2	6.2	7.1
3.0	5.91	1.18	2.0	3.2	6.2	8.4
3.5	6.23	1.25	2.63	3.2	6.2	9.6
4.0	6.51	1.31	2.97	3.2	6.2	10.4

Table 6.26: Comparison of parameters in all three VCO's

VII. CONCLUSION

In this paper important parameter to measure VCO performance are been studied. Different types of VCO's such as Conventional LC tank VCO, Active inductor VCO and Switched capacitor VCO are simulated using cosmoscope spice tool and parameters like frequency and power have been measured. Phase noise is being analysed for all the VCO's. The comparisons of parameters for all different VCO's are tabulated. We can conclude that power and frequency increase with respect to time, but problem from the LC Tank VCO circuit is that it has tuning capability till 3.2Ghz after that frequency doesn't change in big scale. TO more tuning and good power performance active inductor are used in circuit. The tuning of switch capacitor is more than other two circuits. A FM modulator is simulated using switched capacitor VCO.

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