International Journal of Scientific Research in Computer Science, Engineering and Information Technology

ISSN : 2456-3307 OPEN ACCESS

Available Online at : www.ijsrcseit.com

doi : https://doi.org/10.32628/IJSRCSEIT

Low power, low voltage LC VCO design and analysis using 32nm CMOS technology

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ARTICLEINFO

Article History:

Accepted: 01 Sep 2023

Published: 12 Sep 2023

Publication Issue

Volume 9, Issue 5

September-October-2023

Page Number

87-97

ABSTRACT

The metal–oxide–semiconductor field-effect transistor (MOSFET, MOS-FET, or MOS FET) is a transistor used for amplifying or switching electronic signals. CMOS is a Complementary Metal Oxide Semiconductor which is a combination of PMOS & NMOS. This technology is used because of it very low power dissipation. VCO is a Voltage Control Oscillator, in which the output frequency is controlled by its input controlled voltage. By using both of these in a combination, different VCO topology based on ring oscillator can be implemented A current mirror is a circuit designed to copy a current through one active device by controlling the current in another active device of a circuit, keeping the output current constant regardless of loading.

For simulation of these VCO Tanner EDA is used, in which EDA is an Electronic Design Automation. The 13 version of Tanner EDA tool is used for simulation. CMOS VCO can be used in various applications. Some are Phase Locked Loop (PLL), frequency generator, testing circuits etc. In this VCO topology, we have used supply voltage of 1.2 V.

Keywords : CMOS, VCO, MOSFET, PMOS, NMOS, PLL.

I. INTRODUCTION

VCO are by and large used in instrumentation and correspondence structures. Particular turn of events and market requirements premium for High frequency generation.vco are furthermore used in pacemaker. A voltage-controlled oscillator or VCO is an electronic oscillator planned to be controlled in faltering frequency by a data voltage. The frequency of faltering is changed by the associated DC voltage.

Voltage-controlled oscillator or VCO is an electronic circuit that usages escalation, input, and a resonating circuit to make a reiterating voltage waveform. The frequency, or rate or emphasis per unit of time, is variable with an associated voltage, while pivoting current sound or different sign may be reinforced into the VCO to create frequency change (FM).For high-frequency VCOs, the voltage-controlled part is customarily a varicp related in a typical LC oscillator of some construction. For low-frequency VCOs.

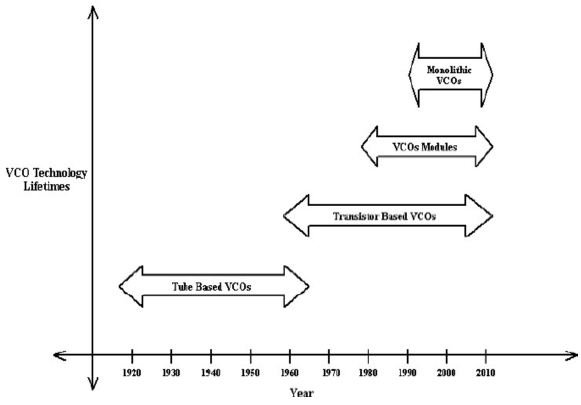

Fig.1.1 (a) Block Diagram of PLL in Used of VCO

Fig 1.1 (b) Evolution of VCO Technology of late, there has been a strong improvement in the state of the art distant data and voice correspondence models in different frequency gatherings. Current handsets for the distant correspondence contain many construction squares, for instance, low-clamor enhancers (LNAs), blenders, frequency synthesizers (FS), channels and intensifiers. With the movement of radio frequency (RF) advancement and essential for more coordination, new RF remote designs are required. There is an enormous interest of compact correspondence and distant correspondence systems in the current life. This has set specific obstructions and essentials on the correspondence channel move speeds and isolating. The state of the art distant correspondence structures rely vehemently upon frequency change and trading of one frequency band to other frequency gatherings.

Recurrence synthesizer is quite possibly of the most fundamental fragment in the distant handset. It essentially impacts the overall execution of the distant handset structure. Recurrence synthesizers are for the most part used as a close by oscillator (LO) in the far off handsets for recurrence understanding and channel decision.

The key idea is to down adherent the RF sign to the baseband sign and it is generally called direct change or zero-IF recipient. To evade the deficiency of information, the down change should give quadrature respects the recurrence and stage changed signals. Thusly, recurrence synthesizer requires the exact quadrature signal age from neighborhood oscillator (LO). RF handsets require quadrature sign and quadrature voltage controlled oscillator (QVCO) offers the best response for the age of the quadrature signal.
Another age of remote handsets is being coordinated into CMOS innovation. This incorporates the advanced and blended simple computerized baseband circuits, which impact the decision of radio handset designs. The CMOS innovation calls the end of discrete segments in the support of abnormal state on chip coordination. All in all, there are different advancements accessible for the radio frequency coordinated circuits (RFICs) execution.

The oscillators are the real bottleneck for the framework on-chip (SOC) acknowledgment of the remote handsets. The oscillator assumes a significant job in the exhibition of remote handsets. Voltage controlled oscillator (VCO) phantom immaculateness execution can restrain the RF handset's exhibition. Voltage-controlled oscillator or VCO is an electronic circuit that utilizations enhancement, input, and a full circuit to create a rehashing voltage waveform. The frequency, or rate or reiteration per unit of time, is variable with a connected voltage, while substituting current sound or different sign might be bolstered into the VCO to create frequency adjustment (FM).For high-frequency VCOs, the voltage-controlled component is usually a varicap associated in a conventional LC oscillator of some structure. For low-frequency VCO.

II. LC-VCO AND VCO PARAMETERS

1.1 Oscillator

Oscillator creates a period fluctuating result when dc voltage is applied. The circuit ought to have self-supporting instrument which adds its own commotion to create and at last it turns into a sign that rehashes the same thing. A negative input framework might sway or we can say oscillator is a seriously planned criticism intensifier. Think about a basic input framework.

This relies upon the possibility that a tuned circuit, once fortified, will influence reliably expecting there is no resistive part present to disperse the energy. It is the limit of the enhancer to create the negative obstruction or stay aware of swaying by giving a proportion of energy comparable to that spread. The assurance of the circuit geography is coordinated by a couple of components:

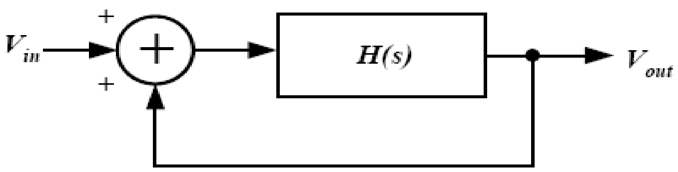

Fig.2.1 Feedback oscillator

$$\frac{Vout}{Vin}(s) - \frac{H(s)}{1 - H(s)}$$

Barkhausen's criteria

a) At the swaying recurrence, the increase should be solidarity: H(jω0)=1

b) At the swaying recurrence, the a stage shift in the know, should be zero: H(jω0)=00 (3600)

LC-VCO (Voltage Controlled Oscillator)

One more kind of sine-wave generator uses inductors and capacitors for its repeat choosing framework. This sort is known as the LC Oscillator. LC oscillators, which use tank circuits, are consistently used for the higher radio frequencies. They are not sensible for use as extremely low- repeat oscillators in light of the fact that the inductors and capacitors would be huge in size, overpowering, and costly to manufacture. There are a couple of arrangements for LC oscillator's. The most notable are the Hartley, Colpits and Clapp oscillators

LC oscillator's topologies

Colpits Oscillator
Hartley Oscillator
Clapp Oscillator

Colpits Oscillator

It is genuinely similar to the shunt supported Hartley circuit beside the way that rather than having a tapped inductor, it involves two game plan capacitors in its LC circuit. With the Colpitts oscillator the relationship between these two capacitors is used as within tap for the circuit

A colpitts oscillator comprises of a solitary semiconductor and LC gadget. The capacitors and inductors decide the swaying recurrence of the circuit. The colpitts oscillator and it's identical circuit model is displayed in Fig. The ongoing through the equal blend of Lp and RT is Vout/(Lps)

+ Vout/RT and current through C1 is equivalent to Iin–Vout/(Lps)–Vout/RT which brings about the articulation given by Eq.

$$V_1 = -\left(I_{in} - \frac{V_{out}}{L_p s} - \frac{V_{out}}{R_T}\right)\frac{1}{C_1 s} \quad (2.1)$$

The current through C2 is (Vout +V1) C2s and the sum of the currents at output node results in Eq.

$$\frac{V_{out}}{I_{in}} = \frac{R_T L_{ps}(g_m + C_2 s)}{R_T C_1 C_2 L_p s^3 + (C_1 + C_2) L_p s^2 + \left(g_m L_p + R_T (C_1 + C_2)\right) s + g_m R_T} \quad (2.2)$$

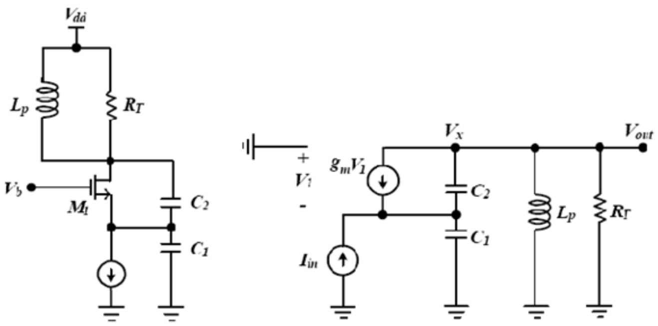

Fig 2.2(a) Circuit of Colpitts LC Oscillator and (b) equivalent diagram

In Eqn. (2.2) if C1 = 0 the above equation reduces to (Lps k RT). The oscillator oscillates if the closed loop transfer function goes to infinity at an imaginary value of s, sR = jwR and both of real and imaginary parts drops to zero at this frequency.

$$-R_T C_1 C_2 L_p \omega_R^3 + \left[g_m L_p + R_T (C_1 + C_2) \right] \omega_R = 0 \tag{2.3}$$

$$-(C_1 + C_2) L_p \omega_R + g_m R_T = 0 \tag{2.4}$$

Eqn (2.4) , the gmLp _ RT (C1 + C2) and results in the following expression given in

$$\omega_R^2 = \frac{1}{L_p \left(\frac{C_1 C_2}{C_1 + C_2} \right)} + g_m R_T \tag{2.5}$$

From Eq. (2.5) the expression can be written as in Eq. (2.6)

$$g_m R_T = \frac{(C_1 + C_2)^2}{C_1 C_2} \tag{2.6}$$

where gmRT is the voltage gain from the source of the M1 to the output if (gmb = 0). This shows the minimum required gain to start the oscillation

$$g_m R_T \geq 4 \tag{2.7}$$

However, in previous calculations capacitance Cp is neglected which appears in parallel with inductor. In Eq. (2.7), the capacitance Cp is included, the expression becomes Eq. (2.8)

$$\omega_R^2 = \frac{1}{L_p \left(C_p + \frac{C_1 C_2}{C_1 + C_2} \right)} \tag{2.8}$$

Where $\omega = 2\pi f_0$

$$f_0 = \frac{1}{2\pi\sqrt{LC_{eq}}} .$$

where Ceq = C1 C2 /(C1+ C2)

Advantages

Simplicity and robustness.

Capacitively coupled circuit that provides better frequency stability than the Hartley oscillator.

Disadvantages

The voltage divider contains the variable capacitor (either C1 or C2) which makes the input voltage be variable also, now and then making the circuit more averse to accomplish swaying over a part of the ideal recurrence extend

Hartley Oscillator

A LC electronic oscillator gets its contribution from a tapped circle in lined up with a capacitor (the tank circuit). A Hartley oscillator is thusly a kind of inductively coupled variable repeat oscillator. Hartley oscillators may be game plan or shunt fed

$$f_0 = \frac{1}{2\pi\sqrt{L_{eq} C}}$$

Where eq L = L1+L2+2M and M is the mutual coupling between inductors L1 and L2.

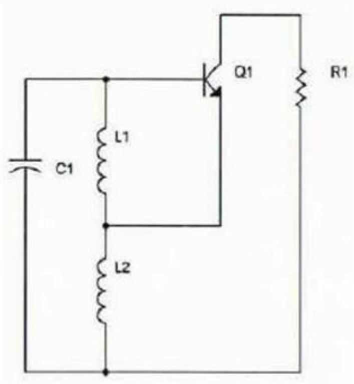

Fig 2.3 Circuit of Hartley LC Oscillator

Advantages

a) Frequency differed utilizing a variable capacitor
b) Output sufficiency stays consistent over the tunable recurrence extend
c) Feedback proportion of tapped inductor stays consistent

Disadvantages

a) Harmonic-rich content
b) Not suitable for a pure sine wave

Clapp Oscillator

It is a rare example of sorts of electronic oscillator worked from a semiconductor (or vacuum tube) and a positive analysis coordinate, the framework is involved a single inductor and three capacitors, with two capacitors (C1 and C2) molding a voltage divider that concludes the proportion of info voltage associated with the semiconductor input. The Clapp oscillator is a Colpitts oscillator with an additional capacitor set in game plan with the inductor.

The Colpitts and commend oscillators are capacitively coupled circuits that give favored repeat unfaltering quality over the Hartley oscillator. In each arrangement, a semiconductor is used as a sign speaker and a resistor is used as a criticism gadget.

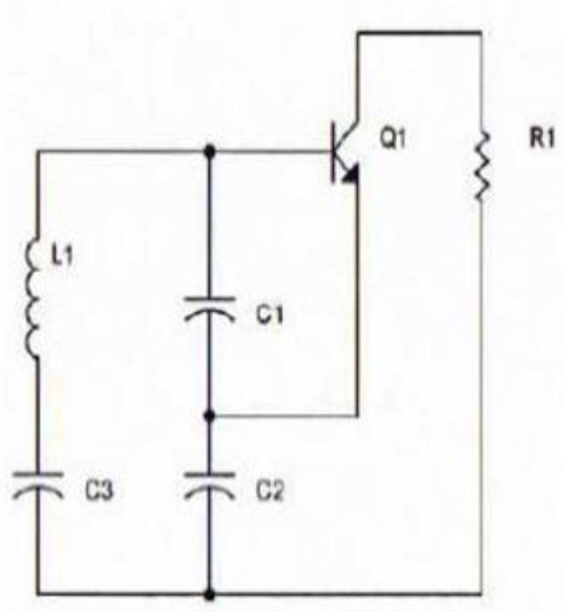

Fig 2.4 Circuit of Clapp LC Oscillator

$$f_0 = \frac{1}{2\pi\sqrt{\frac{1}{L}\left(\frac{1}{C1}+\frac{1}{C2}+\frac{1}{C3}\right)}}$$

Advantages

a) Preferred over a Colpitts circuit for building a variable recurrence oscillator (VFO)
b) Uses a solitary variable capacitor to change the recurrence.
c) By utilizing fixed capacitors in the voltage divider and a variable capacitor (C3) in arrangement with the inductor, there is no issue in accomplishing wavering over a bit of the ideal recurrence go.
d) Higher stacked Q than the Colpitts oscillator.

Different topology of VCO

The VCO can be realised in three ways

Ring Oscillators

Relaxation Oscillators

Tuned or LC Oscillators

Ring Oscillators

Ring oscillators comprise of an odd number of single-finished inverters or an even/odd number of inverters with the suitable associations and this is portrayed in detail in the following part. It is basically utilized in certain applications because of its wide tuning-run, high mix and little format territory. The wavering recurrence is straightforwardly identified with the defer time of every inverter, bringing about high affectability to process and temperature varieties. Its nonlinear voltage-to-recurrence move trademark gives high VCO gain at low frequencies.

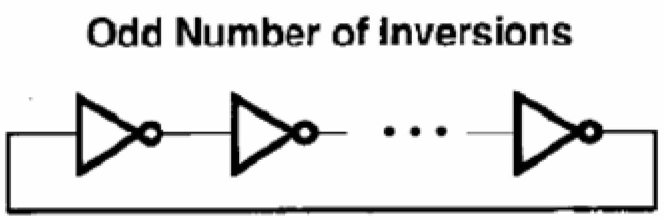

Fig. 2.5 Block Diagram of Ring Oscillator

Relaxation Oscillators

Between two threshold levels, relaxation oscillators alternately charge and discharge a capacitor wit h a steady current.

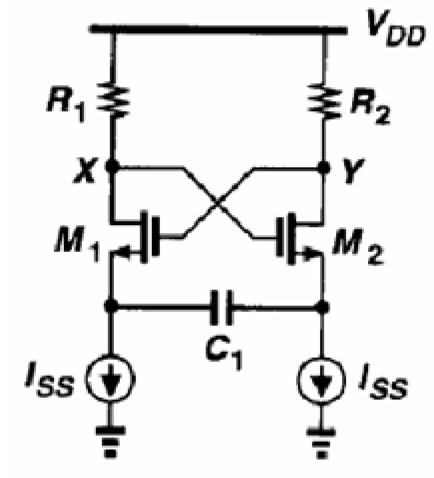

Fig. 2.6 Relaxation Oscillator

Tuned or LC Oscillators

Tuned oscillators contain an unapproachable resonator-LC tank, transmission line resonator, jewel, SAW - that fills in as the repeat setting part. They are all the more genuinely to arrange basically because of the shortfall of great reserved inductors in standard IC Advancements and considering their tremendous size. Nevertheless, they have significantly higher repeat robustness and ridiculous ethicalness since it is set by the inert resonator. They make their AC waveform with the assistance of an inductor-capacitor tank. Contribution to an enhancer is used to assist with keeping up faltering and to diminish damping. The repeat of the oscillator yield is constrained by the condition:

$$F_{osc} = \frac{1}{2\pi\sqrt{LC}}$$

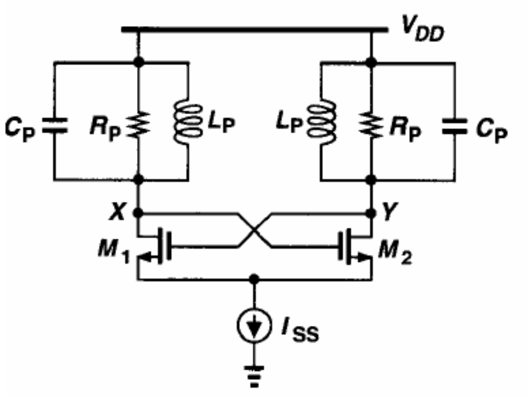

Fig. 2.7 LC Oscillator

If a varactor (a semiconductor device having a voltage dependent capacitance) is used instead of t he capacitor, an input voltage can tune the frequency.

Parameters of VCO

Oscillator execution relies upon different boundaries. A portion of the significant boundaries, for example, stage commotion issues and figure of legitimacy will be examined in the accompanying segment

- Phase Noise
- Figure of merit (FOM)
- Frequency Tuning Range

III. DESIGN OF LC-VCO

CMOS Voltage Controlled Oscillator

To figure out the design equations for the LC-VCO. The total capacitance of variable capacitor.

C tot = Q/V.

Where C tot is the LC-VCO total capacitance. And Q is the electron charge its value is that

Q=1.6 * 10-19 Colum

The oscillation frequencies of the signal switch LC-VCO.

$F = 1/ 2\pi \sqrt{LC}$.

The average power dissipated by the VCO is

$P=CV^2F$.

There are CMOS LC-VCO topology

LC-VCO

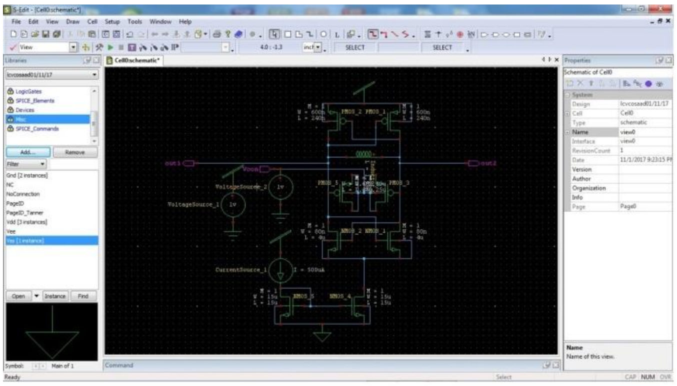

Fig 3.1 Schematic circuit of LC-VCO

T-SPICE

```
* Expand paths: yes
* Wrap lines: no
* Root path: D:\saad lcvco17
* Exclude global pins: no
* Control property name: SPICE

********* General section - Simulation Settings *********
********* Parameters and SPICE Options - Simulation Settings *********
*-------- Devices: SPICE.ORDER > 0 --------
LInductor_1 out1 out2 L=1n
MNMOS_1 out2 out1 N_1 N_1 NMOS W=4u L=70n AS=3.6p PS=9.8u AD=3.6p PD=9.8u MNMOS_2 N_1 out2 out1 N_1 NMOS W=4u L=70n AS=3.6p PS=9.8u AD=3.6p PD=9.8u MNMOS_3 N_1 N_2 Vss Vss NMOS W=18u L=70n AS=13.5p PS=31.8u AD=13.5p PD=31.8u MNMOS_4 Vss N_2 N_2 Vss NMOS W=18u L=70n AS=13.5p PS=31.8u AD=13.5p PD=31.8u MPMOS_1 out2 out1 Vdd Vdd PMOS W=2.5u L=70n AS=2.25p PS=6.8u AD=2.25p PD=6.8u MPMOS_2 Vdd out2 out1 Vdd PMOS W=2.5u L=70n AS=2.25p PS=6.8u AD=2.25p PD=6.8u MPMOS_3 Vcon out2 Vcon Vcon PMOS W=4u L=70n AS=3.6p PS=9.8u AD=3.6p PD=9.8u MPMOS_4 Vcon out1 Vcon Vcon PMOS W=4u L=70n AS=3.6p PS=9.8u AD=3.6p PD=9.8u
VVoltageSource_1 Vdd Vss DC 1 VVoltageSource_2 Vcon Gnd DC 500m ICurrentSource_1 Vdd N_2 DC 500u
********* Analysis section - Simulation Settings *********
.include "C:\Users\abc\Desktop\model_files\tanner models\70nm.md"
.tran 50n 50000000n
.print tran v(out1) v(out2) v(Vcon)
********* Additional SPICE commands - Simulation Settings *********
.end
```

IV. Simulation Results

The LC-VCO circuit stimulated using Tanner EDA T-spice simulator.

The single switch LC-VCO draws maximum 2.5GHZ frequency from supply voltage of 1V.

W-Edit

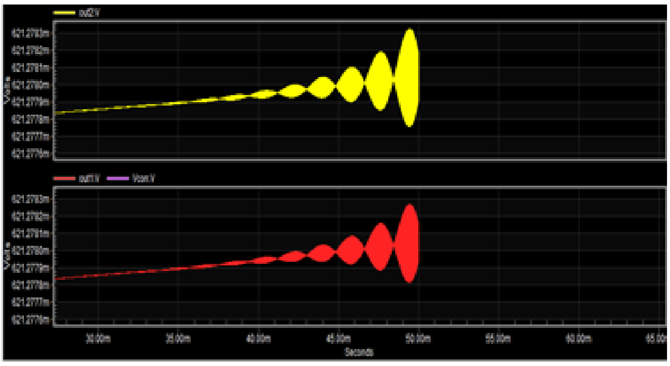

Fig 3.2 Simulation result

V. Related Works

"Design and Implementation of the Quadrature Voltage Controlled Oscillator for Wireless Receiver Applications Utilizing 0.13 μm and 0.18 μm Deep Sub-Micron RF CMOS Technology" by Saeed Zafar from University Technology Petronas.

"Design of a 2.2-4.0 GHz Low Phase Noise and Low Power LC VCO" by Namrata Prasad1,
R. S. Gamad2 and C. B. Kushwah3 in this "a plan of a consolidated Voltage Controlled Oscillator (LC-VCO) with high faltering repeat, Low power usage and Low Phase commotion. For getting the presentation limits, the arrangement was copied in 0.18μm CMOS advancement. Eventual outcomes of the current stoop shows that the wavering recurrence of VCO is 2.2GHz to 4.0 GHz; the power use of the VCO at swaying recurrence of 2.2GHz is 16.13 mw and stage upheaval 143 mdb/HZ. Also at 3.3 GHz and 4.0 GHz is 15.76 mW and 15.31mW with stage upheaval - 151 mdb/Hz and -207mdb/Hz exclusively. We have pondered the results of the ongoing arrangement with earlier disseminated work and is presented in table."

"Implementation of CMOS Low-power Integer-N Frequency Synthesizer for SOC Design "By Debashis Mandal and T. K. Bhattacharyya in this "execution of a recurrence synthesizer for framework on-chip (SOC) plan. The epi-automated CMOS process is used to give SOC plan. This work bases on low-power use to achieve longer life-time of batteries. A 2.4GHz recurrence synthesizer has been made in 0.18μm epi-progressed CMOS development for ZigBee applications, which consumed 7.95mW from 1.8V stock."

"A 30-MHz Low-Jitter High-Linearity CMOS Voltage-Controlled Oscillator" by MYLES H. WAKAYAMA ANDASAD A. ABIDI, MEMBER, IEEE in this "a totally strong voltage-controlled oscillator (VCO) with an on-chip timing capacitor and a most outrageous swaying recurrence of 30 MHz will be represented. Using an original on-chip servo circle, the VCO shows under O.17- percent nonlinearity in its voltage-recurrence move work from 1 to 15 MHz without making due. An unrivaled circuit geology that gives a tremendous swing on the situation capacitor allows the VCO to obtain a cycle-to-cycle jitter of under 100 ppm. The circuit deals with a 5-V stock, and has a kick the container size of 104 mil X 154 bother".

"Phase Noise and Jitter in CMOS Ring Oscillators" by Asad A. Abidi, Fellow, IEEE in this "A direct, genuinely based examination address the uproar processes in CMOS inverter-based and differential ring oscillators. A period space jitter assessment method is used to research the effects of monotonous sound; inconsistent VCO change most obviously addresses gleam (1) commotion. Assessment shows that in differential ring oscillators, dreary sound the differential sets overpowers the jitter and stage commotion, while the stage clatter on account of glint clamor

arises essentially from the tail current control circuit. This is endorsed by generation and assessment. Clear enunciations for period jitter and stage commotion engage manual arrangement of a ring oscillator to specifics, and guide the choice among ring and LC oscillator".

"A 1-V CMOS VCO For 60-GHz Applications" by Tang-Nian Luo, Shuen-Yin Bai, Yi-Jan Emery Chen, Hsin-Shu Chen, and Deukhyoun Heo in this " An organized 1-V, 50-GHz CMOS voltage- controlled-oscillator (VCO) is presented for the emerging 60-GHz UWB applications. Executed in a business 0.18μm CMOS development, the middle VCO equipment consumes 4mW of power and includes only 90μm×120μm of the silicon estate. The first rate factor line inductors and NMOS varactors are used to foster the LC-resonators. The conscious stage upheaval at 1-MHz offset from 49 GHz is - 96 dBc/Hz, which prompts a brilliant Figure-of-Merit (FOM) of - 184 dBc/Hz "

Problem Formulation

The field of high-repeat circuit setup is getting enormous mechanical thought due to arrangement of radio repeat and microwave applications. This work proposes the low control, low stage uproar and low stage botch quadrature voltage controlled oscillator for distant recipient applications. A superior assessment and plan of the low control, low stage upheaval and low stage botch quadrature voltage controlled oscillator is finished conversely, with common. The construction, utilization and depiction of the proportional is finished with the joining of 40 source damping resistor (Rdmp), tail biasing resistor (Rtail) and multifinger entryway width course of action of the pMOS varactors and 50 impedance of typical channel yield supports. The execution is finished using 0.18 μm, 6 metal, 1 poly, 1.8 V and 0.13 μm, 8 metal, 1 poly, 1.2 V significant sub-micron CMOS and RF CMOS process developments.

Wave Generators assume a noticeable job in the field of hardware. They produce signals from a couple of hertz to a few gigahertz (109 hertz). Current wave generators utilize a wide range of circuits and create such yields as sinusoidal, square, rectangular, sawtooth, and trapezoidal waveshapes.

VI. CONCLUSION

Tracks the authentic setting of voltage-controlled oscillators (VCOs) since around 1910. Gives occurrences of VCO coordination in RF ICs. Presents development, execution and size headway to the current date. Considering history and advancement, future examples are expected

Voltage-controlled oscillators (VCOs) are consistently tracked down in far off systems and various correspondences structures that should tune over a band of frequencies. VCOs are open from a wide extent of creators in a grouping of pack styles and execution levels. Present day surface- mount and radio-repeat composed circuit (RFIC) VCOs regardless, owe their inheritance to

planning progressions that began pretty much 100 years back. Updates in VCO development have continued all through that time, yielding ever smaller sources with further developed stage upheaval and tuning linearity.

Oscillators have been basic parts from the time Edwin Armstrong tracked down the heterodyne rule. In this application, an oscillator urges sinusoidal sign to a nonlinear mixing part to influence repeat translation by copying the oscillator's sign with other data signals. Clearly, Armstrong comprehended that what he expected to control the repeat understanding was an electrical circuit which made a stable sinusoidal time-evolving voltage (or stream) with a contrasting repeat. He figured out around that identical opportunity that an Audion (an early vacuum tube) could be set up to make an influencing, and he satisfactorily imagined the primary electronic oscillator (rather than the crude shimmer opening oscillators used in early distant transmitters).

VII. FUTURE SCOPE

a) Implementation of this plan will give better control usage, stage noise, tuning degree and FOM.
b) It is furthermore significant for RF correspondence structure where the low stage disturbances, low control use, wide tuning degree are the essential necessities.
c) In our proposed plan we use a lone stage VCO with no mirror, with tail present and after that we remember current mirror for improvement for its boundary which will end up helpful for VCO client and makers.
d) Taking the plan level up to creation.
e) Improve the influencing repeat run.

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Cite this article as :

Sonu Kumar, Ateek Mansoori, "Low power, low voltage LC VCO design and analysis using 32nm CMOS technology", International Journal of Scientific Research in Computer Science, Engineering and Information Technology (IJSRCSEIT), ISSN : 2456-3307, Volume 9, Issue 5, pp.87-97, September-October-2023.