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Implementation of types of VCO

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Abstract: A Voltage Controlled Divider (VCO) is a basic building block in most of the electronic systems. Phase-locked loop (PLL), tone synthesizers, Frequency Shift Keying (FSK), frequency synthesizers, etc make use of VCO's to generate an oscillating frequency that can be decided with the help of components. Voltage Controlled Divider can be implemented for analog applications. The project proposes three types of VCO using Electric tool and LT Spice XVII tool. The three VCO's that are implemented are CMOS Ring Oscillator, Colpitts Oscillator and Relaxation Oscillator. These circuits generate two oscillating frequencies that is decided by the circuit components.
Keywords: Voltage Controlled Divider (VCO), CMOS Ring Oscillator, Colpitts Oscillator, Relaxation Oscillator, oscillating frequency.

I. INTRODUCTION

Oscillator is a circuit that produces a repetitive continuous alternating waveform without any input. Unidirectional current from DC input is converted into an alternating waveform of the desired frequency (decided by its circuit components). Oscillators are usually classified based on the frequency of their output signal. When an oscillator produces a frequency below 20 Hz, it is called as Low Frequency Oscillator (LFO). LFO is an electronic oscillator used in the audio synthesizers. An audio frequency oscillator generates frequency of 16 Hz to 20 kHz in the audio range. An RF oscillator generates frequency of 100 kHz to 100 GHz in the Radio Frequency (RF) range.

A Voltage Controlled Oscillator (VCO) is an oscillator whose oscillation frequency of output signal can be varied over a range. This can be controlled by input voltage. The oscillating frequency varies from few Hz to few hundreds of GHz. Input DC voltage can be varied to adjust the frequency of produced output signal.

These voltage controlled oscillators are widely used in Phase Locked Loops (PLLs), in which the oscillator's frequency can be locked to the frequency of another oscillator. These are present in modern communication circuits that are used in filters, modulators, demodulators, and forming the basis of frequency synthesizer circuits. These are used to tune radios and televisions. In modern electronics, crystal oscillators produce frequencies from 32 kHz to over 150 MHz, with 32 kHz crystals.

In an oscillator circuit, a varactor diode is connected to the tuned circuit or resonator to obtain radio frequency VCO. Capacitance is changed by changing the DC voltage across the varactor. Thus the resonant frequency can be changed by the tuned circuit. By charging and discharging the energy storage capacitor with a voltage controlled current source, we can construct voltage controlled relaxation oscillator. Rate of charging the capacitor can be increased by increasing the input voltage and decreasing the time between switching events.

The instantaneous oscillation frequency can be determined by the applied input voltage. Modulating signals applied to control input causes Frequency Modulation (FM) or Phase Modulation (PM). Voltage Controlled Oscillator is a part of Phase Locked Loop and transceiver. This is shown in Fig. 1.

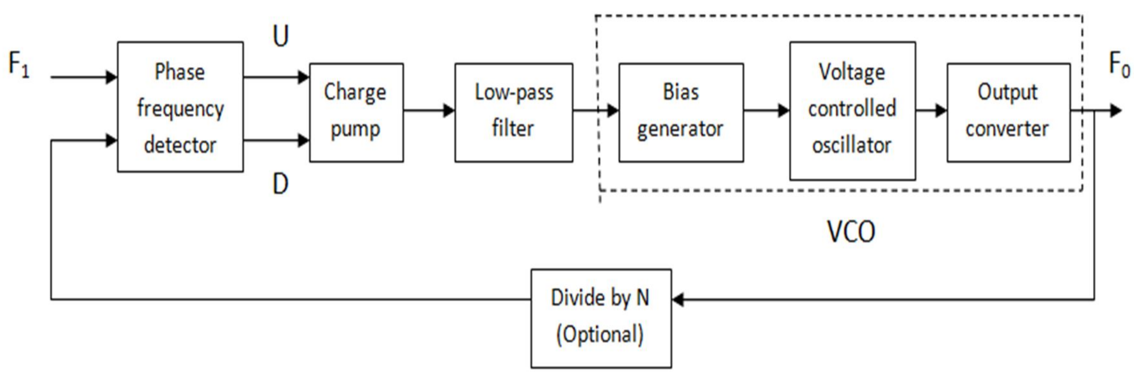

Fig. 1 Block diagram of PLL

Many other electronic systems including wireless transceivers uses Voltage Controlled Oscillator (VCO) block widely. Noise performance of the VCO determines reception quality of the signals in any wireless standard. The parasitic components are undesired in integrated circuits. This parasitic effect may overcome when they are taken into account during initial phase. Based on the type of waveform produced, VCO's can be generally categorized into two groups. They are:-

A. Harmonic or Linear oscillators

These oscillators generate a sinusoidal waveform. In electronics, harmonic oscillators usually consist of resonator with an amplifier. This replaces the resonator losses in order to prevent the amplitude from decaying. It also isolates the resonator from the output so that load does not affect the resonator. Some examples are LC oscillators and crystal oscillators.

B. Relaxation or Nonlinear oscillators

Relaxation or nonlinear oscillators will produce a non sinusoidal output like square, sawtooth or triangle wave. They are usually used in Integrated Circuits (ICs). They can provide wide range of operational frequencies with minimal number of external components. It consists of energy-storing element (such as a capacitor or an inductor). Relaxation oscillators are used at lower frequencies. They have poorer frequency stability than linear oscillators. Some of the more common relaxation oscillator circuits are multi vibrator, Pearson Anson oscillator, Ring oscillator, Delay-line oscillator and Royer oscillator.

II. DESIGN METHODOLOGY

Three types of Voltage Control Oscillator's (VCO) are proposed in the following section. They are:-

A. CMOS Ring Oscillator

Ring oscillators are made up of a ring of active delay stages. This is a type of linear or harmonic oscillator. The harmonic generator additionally uses associate electronic equipment that includes a feedback to excite resonant oscillations in a resonator by generating a sine wave. Ring oscillator is a device that is composed of an odd number of NOT gates in a ring. The output oscillates between the two voltage levels representing true and false. NOT gates (or inverters) are attached in the form of chain and the output of the last Nth stage inverter is fed back into the first. There exists no stable operation point because of odd number of inversions in ring oscillator. Barkhausen criteria must be satisfied to sustain the oscillation. Also, every stage should add 180°/N phase and the block diagram of N stage (N = odd, >1) ring VCO is shown in Fig 2.

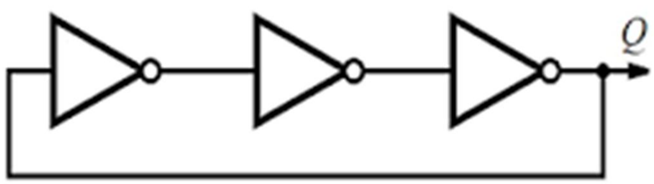

Fig. 2 Block Diagram of N stage Ring Oscillator

The propagation time (t_d) of transition of signal through the complete chain determines the period of ring oscillator and is given by the equation (1) as

$$T = 2 \times N \times t_d \quad (1)$$

Here, N is number of inverters (delay stages) in a chain. Factor 2 results due to the fact that complete cycle requires a low to high and high to low transitions. The equation (3.1) is valid only for ($2Nt_d$) >> (tf + tr) (tr and tf are the rise and fall time periods, respectively). Thus the oscillation frequency can be expressed as shown in equation (2).

$$f_0 = 1/T = 1/(2Nt_d) \quad (2)$$

Hence, oscillation frequency of N-stage ring oscillator can be tuned by varying the time delay of each stage. Also the oscillation frequency is inversely related to and depends only on the delay time (td) and number N of delay stages. Also for given interval of time, signal passes through each stage is twice.

B. Colpitts Oscillator

Colpitts generator was invented by Edwin H. Colpitts. This is an example harmonic oscillator. This oscillator is one in all the designs for LC oscillators and electronic oscillators. It uses both inductors and capacitors to generate oscillation at bound frequency. Colpitts circuit also has Bipolar Junction Transistor (BJT), Field Effect Transistor (FET), Operational amplifier (Op amp) or vacuum tube. These are the gain devices. Output is connected to the input within the variety of feedback containing parallel LC circuit like tuned circuit. Its function is to act sort of a bandpass filter to set the frequency of oscillation.The Colpitts oscillator is electrical twin of Hartley oscillator. The oscillating frequency is given by the equation (3).

$$f_0 = 1/(2\pi\sqrt{(L((C_1*C_2)/(C_1+C_2)))}) \quad (3)$$

Actual frequency of oscillation is slightly lower because of the junction capacitances and resistive loading of the semiconductor transistor. With any oscillator, amplification of the active part ought to be marginally larger than the attenuation of capacitive voltage divider so as to get stable operation.

C. Relaxation Oscillator

Relaxation generator is non linear electronic generator circuit. It produces a non sinusoidal signal that's repetitive output that will be triangle wave or square wave. Circuit consist of an electric circuit consisting of switch device like a semiconductor unit, comparator, relay, op amp. Relaxation oscillator is shown in Fig. 3.

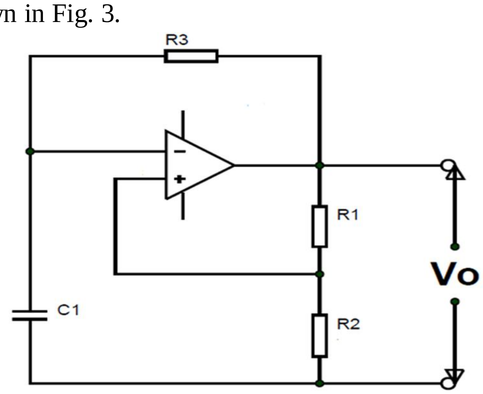

Fig.3 Circuit diagram of Relaxation Oscillator

Oscillator period depends on time constant of either capacitor or inductor. Active device switches between charging and discharging modes. Therefore it produces dis continuously changing repetitive waveform. This can be completely different compared to different sort of electronic oscillators. Relaxation oscillators are used to generate low frequency signals for applications like blinking lights (turn signals) and electronic beepers and in voltage controlled oscillators (VCOs), inverters and switch power provides, dual-slope analog to digital converters and performance generators.

Relaxation generator is additionally applied to dynamical systems in several areas of science. It produces nonlinear oscillations and may be analyzed using a similar mathematical model as electronic relaxation oscillators. The period of a relaxation oscillator is principally determined by the time constant. Initially, if we tend to think that output of the comparator is high, then throughout this point the capacitor will be charging. With the charging of the capacitor, its terminal voltage can gradually rise, which may be seen in the graph as shown in Fig. 4.

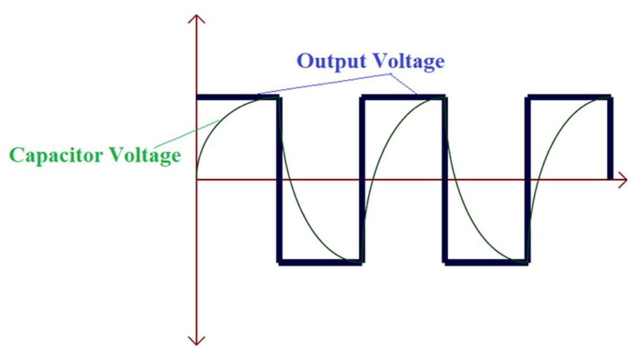

Fig.4 Output waveform of Relaxation Oscillator

Once the capacitor terminal voltage reaches the threshold, the comparator output can go from high to low as shown in Fig.4. Once the comparator output goes negative, the capacitor starts discharging to zero. The capacitor discharges due to the presence of a negative output voltage, it again charges except in the opposite direction. Once the capacitor charges to the utmost in a negative direction, the comparator switches output from negative to positive. Once the output switches to a positive cycle, the capacitor discharges along with the negative path and builds up charges within the positive path as shown in the graph. Therefore the cycle of capacitor charge and discharge in positive and negative paths trigger the comparator produces a square wave signal at the output that is shown above.

The frequency of oscillation depends on the time constant of C1 and R3 within the circuit. Higher values of C1 and R3 can result in longer charge and discharge rates, therefore producing lower frequency oscillations. Similarly, smaller values will generate higher frequency oscillations. The oscillating frequency calculation is shown in equation (4), (5) and (6).

$$f=1/(2*R_3*C_1*\ln((1+k)/(1-k))) \tag{4}$$

Here,

$$k=R_1/(R_1+R_2) \tag{5}$$

If the resistors R_1 and R_2 are equal to each other, then

$$f=1/(2.2*R_3*C_1) \tag{6}$$

III. IMPLEMENTATION AND RESULT

A. CMOS Ring Oscillator

1) Design an inverter using PMOS and NMOS using Electric tool. Since CMOS Ring Oscillator is designed using cascaded inverter of odd number of stages, the proposed implementation of Ring Oscillator is designed by cascading 3 inverters and output of third inverter is given as feedback input to the first inverter as shown in Fig. 5. The input voltage (V_{dd}) of 5V and 3V is applied to the same circuit.

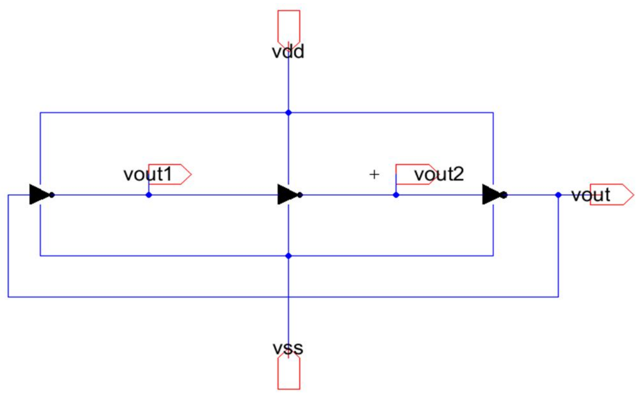

Fig.5 Implementation of three stage CMOS Ring Oscillator

2) The output waveforms of both conditions V_{dd} = 5V and V_{dd} = 3V are shown in Fig. 6 (producing frequency of f=2.75 GHz) and Fig. 7 (producing frequency of f=1.8 GHz) respectively.

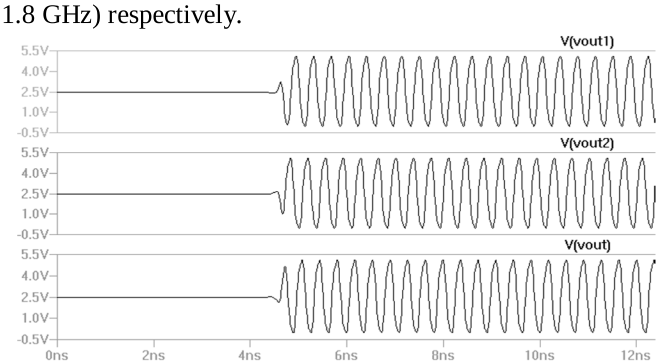

Fig.6 Output waveform of Ring Oscillator when V_{dd} = 5V

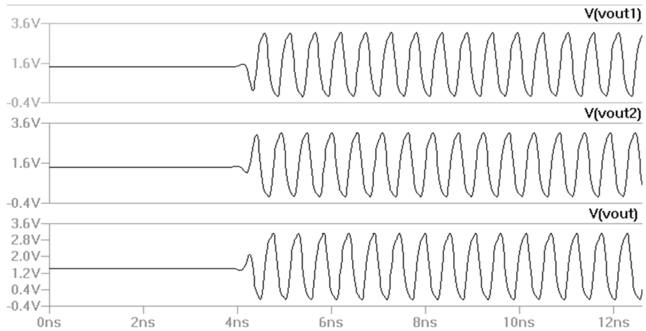

Fig.7 Output waveform of Ring Oscillator when V_{dd} = 3V

B. Colpitts Oscillator

1) The Colpitts Oscillator is designed using L (inductor) and C (capacitor) components, with npn bipolar junction transistor. Theoretically, the values of L and C for oscillating frequency 10 kHz and 20 kHz that satisfy equation 4.3 are shown in Table I.

TABLE I: Values of components to obtain the required oscillating frequency

Oscillating frequency	L (in H)	C_1 (in F)	C_2 (in F)
10 kHz	11.6 m	24 n	240 n
20 kHz	3 m	24 n	240 n

2) Implement the Colpitts Oscillator with obtained component values for oscillating frequency of 10 kHz (to the left) and 20 kHz (to the right) as shown in Fig.8.

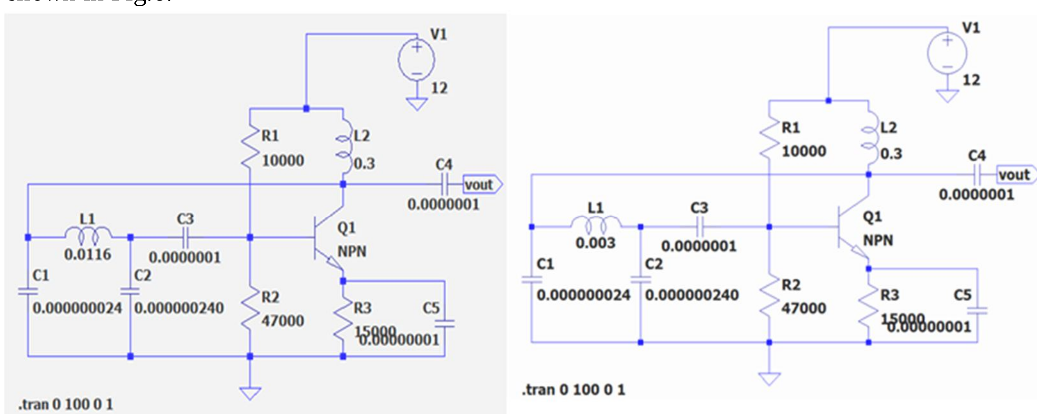

Fig. 8 Colpitts Oscillator to produce oscillating frequency of f = 10 kHz and f = 20 kHz

3) Obtained output waveforms for f = 10 kHz and f = 20 kHz as shown in Fig. 9 and Fig. 10 respectively.

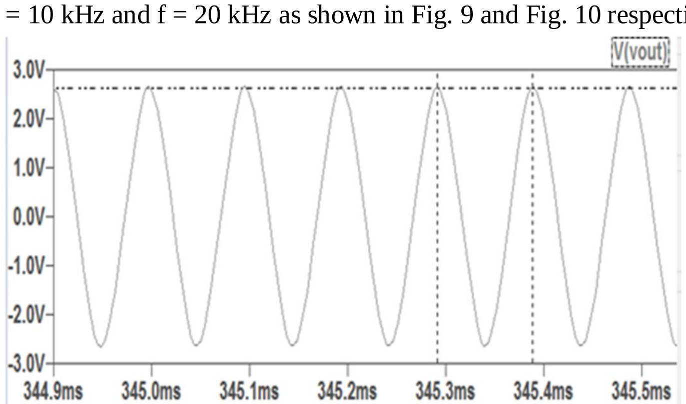

Fig.9 Output waveform for Colpitts oscillator with oscillating frequency of f = 10 kHz

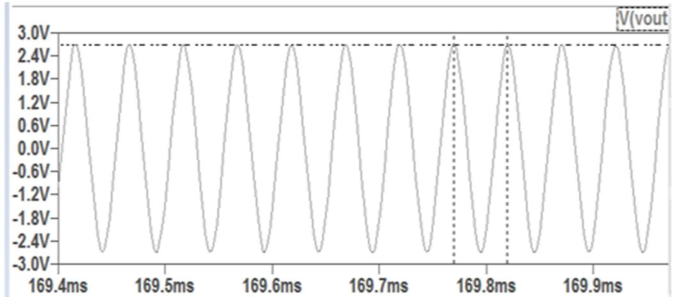

Fig.10 Output waveform for Colpitts oscillator with oscillating frequency of f = 20 kHz

C. Relaxation Oscillator

1) Relaxation oscillator is designed using operational amplifier (Op amp), resistor and capacitor as shown in Fig. 11. Oscillating frequency of 1 kHz is shown in the left side and 2 kHz is shown in the right side.

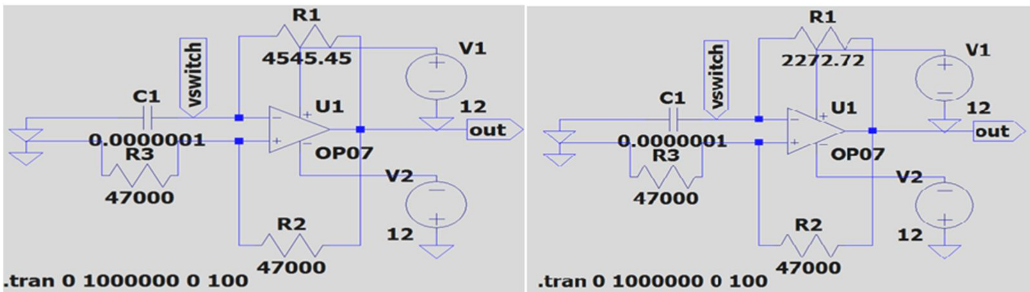

Fig.11 Relaxation oscillator generating oscillating frequency of f = 10 kHz (in left) and f = 2 kHz (in right)

2) Oscillating frequency is theoretically calculated using equation 6. These values are tabulated in Table II.

Table II: Component values and resulting oscillating frequency

C (in F)	R_3 (in Ω)	Oscillating frequency
0.1 µ	4.545 k	1kHz
0.1 µ	2.272 k	2kHz

3) Practically, the output waveform for oscillating frequency of f = 1 kHz and f = 2 kHz is obtained by simulation as shown in Fig. 12 and Fig.13 respectively.

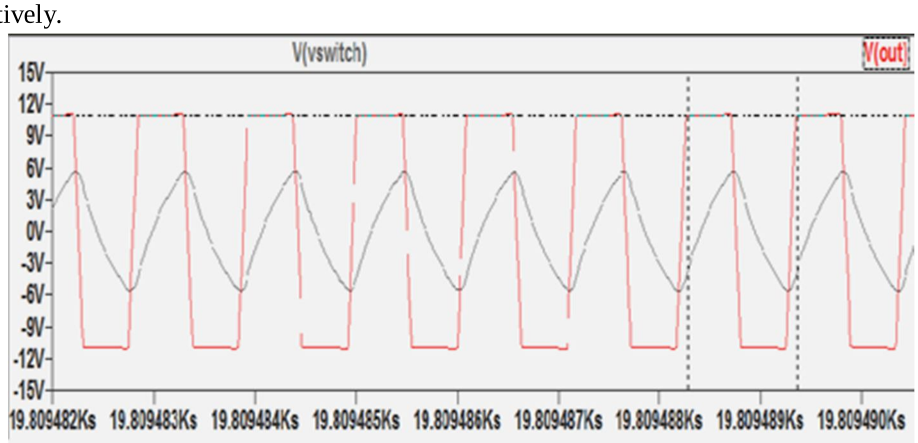

Fig.12 Output waveform of Relaxation oscillator with oscillating frequency f = 1 kHz

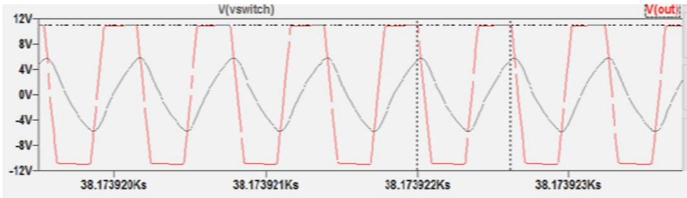

Fig.13 Output waveform of Relaxation oscillator with oscillating frequency f = 2 kHz

IV. CONCLUSIONS

The proposed project is implemented using Electric tool as well as LT Spice XVII tool. There are two types of Voltage Controlled Oscillator's (VCO). They are Harmonic or linear oscillator and Relaxation oscillator. In the proposed project, three VCO's are implemented. They are Ring oscillator, Colpitts oscillator and LC Relaxation oscillator. Among these three, the Ring oscillator and Colpitts oscillator are classified under Harmonic or linear oscillator. Similarly, the LC Relaxation oscillator that is implemented is classified under Relaxation oscillator.

The ring oscillator is implemented using Electric tool. This oscillator is implemented for supply voltage of V_{dd} = 5V and V_{dd} = 3V. The output waveform and frequency is obtained and verified. The Colpitts oscillator is implemented in LT Spice XVII tool. This oscillator is designed for the frequencies of 10 kHz and 20 kHz. The output waveform and obtained frequencies are compared with therotical values and verified. Similarly, the relaxation oscillator is implemented using LT Spice XVII tool. Both inductor (L) and capacitor (C) values are designed to obtain the oscillating frequency of 1 kHz and 2 kHz. The output waveform and obtained frequencies are verified with the therotical values. Output waveforms are observed and frequency values are verified with therotical values.

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REFERENCES

[1] J.Naga Raju, K.Naveen, CH.Sreenu, "CMOS Voltage Controlled Oscillator (VCO) Design with Minimum Transistors", International Journal for Research Trends and Innovation, Volume 1, Issue 3, December 2016.

[2] Rekha Yadav, Pawan Kumar Dahiya and Rajesh Mishra, "Design of optimal high-frequency CMOS VCOs for automotive application", Indian Academy of Sciences, 15 July 2020.

[3] Shruti Suman, Krishna Gopal Sharma, "An Improved Performance Ring VCO: Analysis and Design", Ciência e Técnica Vitivinícola, January 2018.

[4] Paavo Vaananen, Niko Mikkola, Petri Helio, "VCO Design With On-Chip Calibration System", IEEE transactions on circuits and systems, Volume 53, Number 10, October 2006.

[5] Peter Kinget, "Integrated GHz voltage controlled oscillators", columbia.edu, kinget, aacd99 book, 12 June 2007.

[6] Heesauk Jhon, Min-Su Kim, Myounggon Kang, "Cost-Effective 4 GHz VCO Using Only Miniature Spirals Realized in a 0.18 µm CMOS Process for Wireless Sensor Network (WSN) Applications", Electronics, 2019.

[7] V. Macaitis, R. Navickas, "CMOS Technology based LC VCO Review", IEEE conference, 2015.

[8] Madhumita Singh, Sanjeev M. Ranjan, Zoonubiya Ali, "A Study of Different Oscillator Structures", International Journal of Innovative Research in Science, Engineering and Technology, Volume 3, Issue 5, May 2014.

[9] Miss. Megha Manmath Kothale, Prof. S. S. Killarikar, "An Efficient Design of High Performance Different types of Oscillator for WI-FI and ISM bands of applications using 14nm FinFET Technology", International journal of engineering research & technology, Volume 08, Issue 07, July 2019.

[10] E.A. Vittoz, M.G.R. Degrauwe, S. Bitz, "High-performance crystal oscillator circuits: theory and application", IEEE Journal of Solid-State Circuits, Volume 23, Issue 3, June 1988.

[11] Sajotra Deepak, Dhariwal Sandeep, Mishra Ravi Shankar, "Comparative Analysis of Voltage Controlled Oscillator using CMOS", Indian Journal of Science and Technology, Volume 9, Issue 14, 2016.

[12] Erik Lindberg, Reader Emeritus, IEEE Lifemember, "The Oscillator Principle of Nature - A Simple Observation", IEEE, Nonlinear Dynamics of Electronic Systems 2012.

[13] Vikalp Thakur, Virendra Verma, "Low Power Consumption Differential Ring Oscillator", International Journal of Electronics and Communication Engineering, Volume 6, Number 1, 2013.

[14] Zach Wendt, Types of Oscillators: Oscillator Uses in Microcontrollers, Arrow, 31 January, 2020.