Design of a 1 GHz Microwave Oscillator

Submitted by

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Project Title

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Acknowledgement

I, **Rudraprasad Debnath**, a student of **Indian Institute of Technology Tirupati**, MTech 1^{st} year, have completed this project titled **Design of a 1 GHz Microwave Oscillator** under the supervision of **Professor M. V. Kartikeyan**. I would like to convey my heartfelt gratitude to Kartikeyan Sir for his tremendous support and assistance in the completion of my project. I am thankful to him for his immense efforts to teach us new things and growing strong concepts on the subject. It was a great learning experience as well. The project work would not have been completed without his cooperation and inputs.

Regards,
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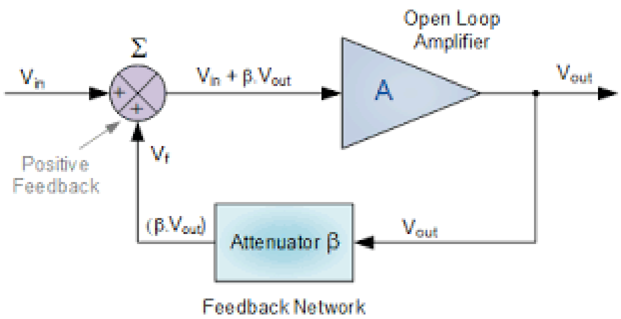
Introduction

A microwave oscillator is an electronic device that generates microwave signals. It converts direct current (DC) electrical power into high-frequency alternating current (AC) signals in the microwave frequency range, typically between 1 GHz and 100 GHz.

The most common type of microwave oscillator is the electronic oscillator, which generates microwave signals by using the feedback loop between an amplifier and a resonant circuit. The resonant circuit is typically a cavity or a transmission line, and the amplifier is usually a solid-state device such as a transistor. The feedback loop keeps the oscillator operating at a specific frequency, and the microwave signal is then extracted from the oscillator and used for various applications, such as in radar systems, communication systems, and microwave ovens.

Microwave oscillators are widely used in many fields of science and technology, and they play a crucial role in modern communication and electronic systems.



The above figure shows the block diagram of a general oscillator. There is a feedback path from the output to the input. A good criterion for a non-linear device to work as an oscillator is to make it unstable and positive feedback can do the task well. So Oscillators are positive feedback devices. Transistor oscillators have made great strides in the last quarter of a century. Silicon bipolar junction transistors have dominated the oscillator field until recently. With low 1/f noise characteristics, Si BJT discrete devices have produced excellent results both in fixed tuned and tunable oscillators at frequencies exceeding 20 GHz. Oscillators are used in RF transceiver circuits to generate a frequency locally (Local Oscillator) to modulate/demodulate a signal.

Types of Oscillator Circuits

There are some oscillator topologies those are useful in the practical fields. They are –

- Colpitt Oscillator
- Hartley Oscillator
- Clapp Oscillator

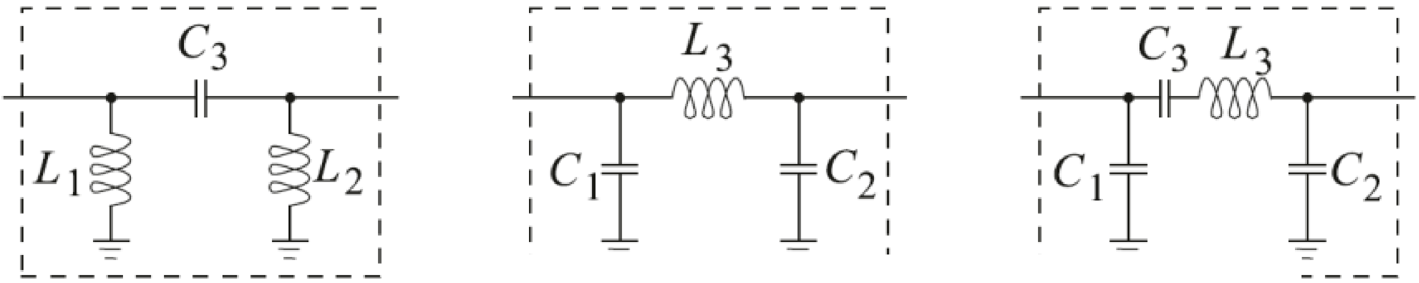
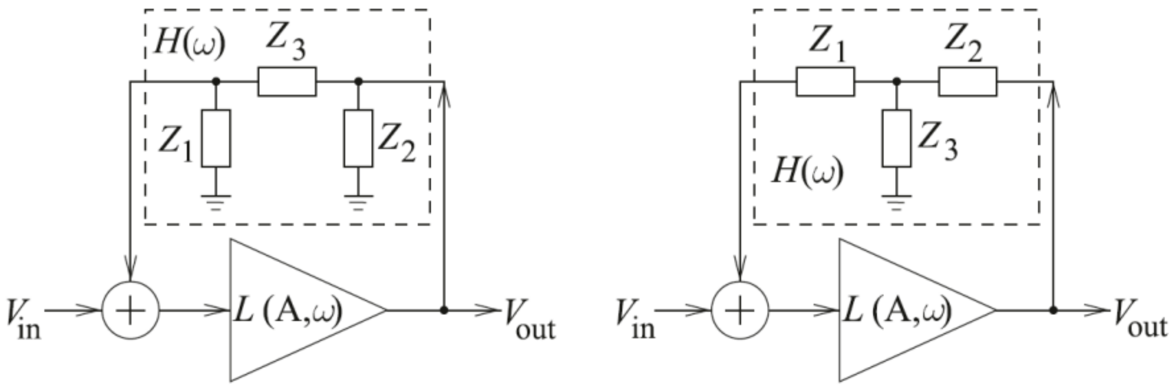


Figure 1: From the left: (a)Hartley, (b)Colpitts (c)Clapp feedback topology

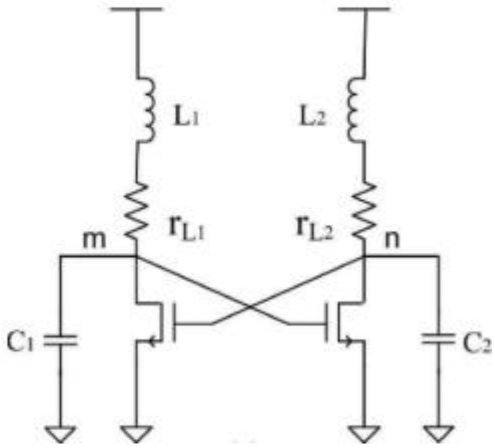
The leftmost circuit consists of two inductors and one capacitor, and it is termed as Hartley topology. Middle one is Colpitts and the last one is Clapp. These all are used as the feedback network required for oscillation.



Two feedback topologies are shown in the above figure. The type and values of the impedances Z_1,Z_2 and Z_3 can be changed to change the topology of the device. Generally the amplifying circuit is a BJT but we can use MOSFET also. There is another topology that is the **Cross-Coupled MOSFET** topology that will be used in the present work.

Cross Coupled Oscillator Topology and Phase noise

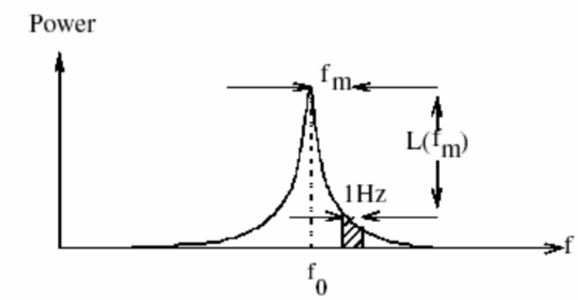
The cross-coupled oscillator topology that is widely used in industry, is an important topology that contains two back-to-back MOSFETs with the gates connected to the drains of each other. The diagram aside shows the basic topology of a cross-coupled microwave oscillator circuit. They are frequently employed as voltage-controlled oscillators in function generators, phase-lock loops, frequency synthesizers, etc. Some of the early stability studies were based on experimental results and linear analysis tools.



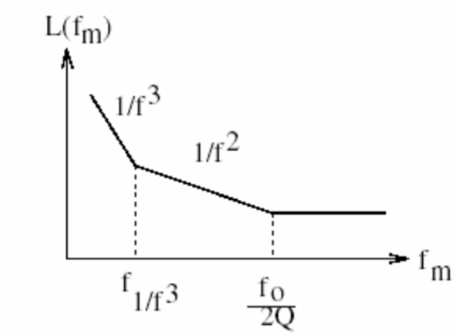
Cross-coupled oscillators are based on the idea of activating a passive LC tank resonator through a differential negative oscillator.

Now what is phase noise?

Phase noise is a measure of oscillator stability and refers to short-term random fluctuations in f or φ. Phase noise is defined as the single-sideband power at a frequency offset f_m from the carrier frequency f o measured in a 1Hz band compared to the carrier power.

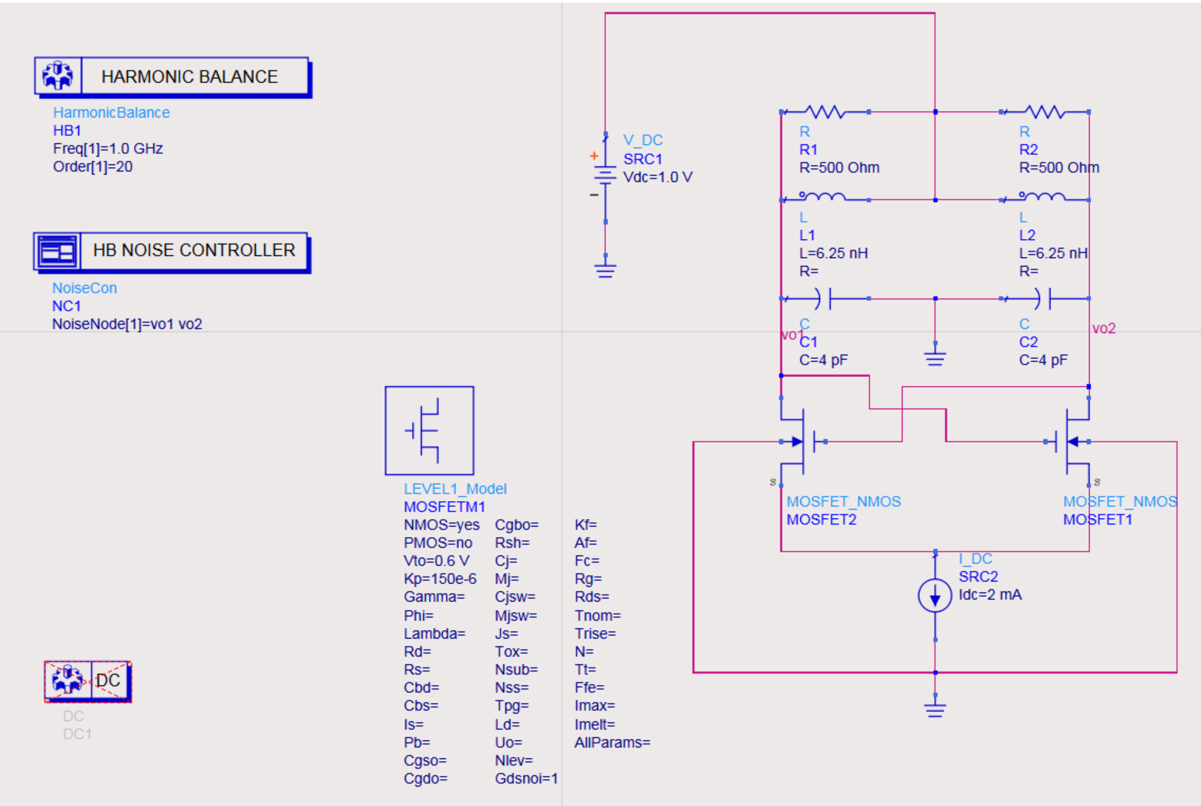


Output power spectrum of differential LC-Tuned VCO

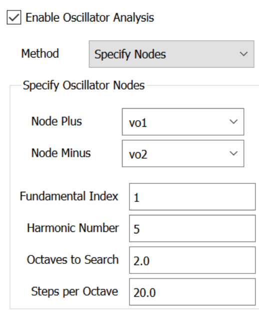


Phase noise variation with frequency offset

Design of Oscillator Circuit in ADS Software and Simulation

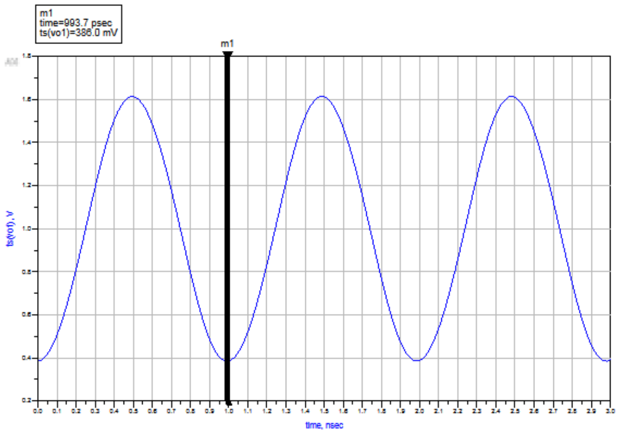


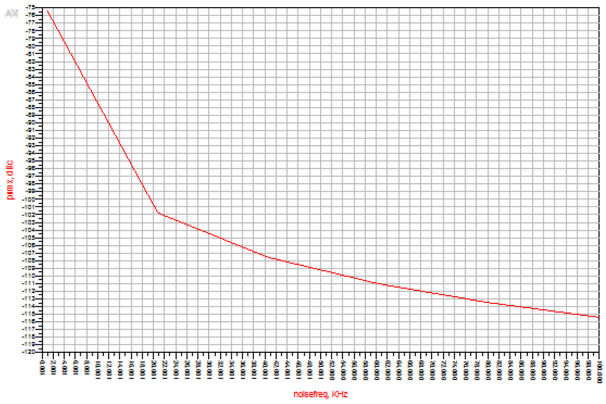
The setup shown above is designed in ADS software. No specific MOSFET library is used for the design. A Parallel LRC circuit can be seen connected to the MOSFETs and the values are set so that a 1 GHz oscillation can be obtained. A 2 mA bias current is connected to the device for proper biasing. A harmonic balance simulation is used to plot the output waveform and a Phase Noise analysis is done using HB Noise Controller. Specifications required for the microwave must be – 1 GHz Centre frequency and more than -70 dBc phase noise at 10 kHz offset. To meet that, the phase noise is measured from 1 to 100 kHz frequency range.



The simulation setup is especially done for the oscillator simulation. The Two nodes are taken as vo1 and vo2.

Results





The results after simulation is presented here. It can be seen that the oscillation frequency is almost perfectly 1 GHz. The phase noise analysis also dhows that at 10 KHz offset, the phase noise is almost -85 dBc.

References

[1] *"Microwave Engineering",* D.M. Pozar, 4th Edition, John Wiley and Sons.

[2] *"9.3–10.4-GHz-band cross-coupled complementary oscillator with low phase-noise performances",* Lin, J., Ma, J. G., Yeo, K. S., & Do, M. A. (2004). 9.3–10.4-GHz-band cross-coupled complementary oscillator with low phase-noise performance. IEEE Transactions on Microwave Theory and Techniques, 52(4), 1273-1278.