ELEN90062 High Speed Electronics

Workshop Two

Cadence Simulation of Voltage Controlled Oscillator and Cascode Amplifier

Welcome to Workshop 2 for High Speed Electronics. This workshop is simulation-based and is implemented using the Cadence software. During this workshop, you will implement a voltage-controlled oscillator (VCO) and a Cascode amplifier and anlyse their performance.

Instructions

- The workshop is worth 5% of your final subject mark
- Refer to Workshop 1, Cadence Tutorial, when implementing and running the simulations.
- You must show the completed simulation tasks to your workshop demonstrator.
- The report should have a brief executive summary detailing the objective of each simulation. The remaining part of the report should consist of the outcome of the tasks below (calculations, plots, etc.).
- The report should clearly show the equations used in calculations.
- The workshop report is due on 31/08/2018 by 5 pm.
- Submit one report per group.

Cadence Simulation 1: Voltage Controlled Oscillators

Oscillators in general, convert a DC input into an AC output. In a LC oscillator, the electrical energy is transferred between a capacitor (C) and an inductor (L) as electrostatic energy and electromagnetic fields, respectively. Consider the LC tank circuit shown in Figure 4, where the capacitor is fully charged. Initially, the capacitor will start discharging, resulting in a decrease in the voltage across the capacitor. The discharging current however, will increase an electromagnetic field across the inductor. When the capacitor is fully discharged, current that creates an electromagnetic field across the inductor ceases. At this point, the entire electrostatic energy is transferred from the capacitor to the inductor. When there is no current to maintain the electromagnetic field at the inductor, the electromagnetic field starts to decrease, resulting in a reverse electro-magnetic field that oppose the current drop. This opposing field, Ldi/dt, then charges the capacitor. This cyclic transfer of of energy between the capacitor and inductor is the reason behind the oscillations in the tank circuit.

The frequency at which the circuit oscillates (resonates) depends on the L and C of the circuit. For the oscillations to occur in the tank circuit, the capacitive reactance should be equal to inductive reactance. This relationship yields the resonance frequency, f, as follows:

$$2\pi f L = \frac{1}{2\pi f C} \tag{1}$$

$$f = \frac{1}{2\pi\sqrt{LC}} \tag{2}$$

For ideal L and C, this cyclic transfer of energy will continue indefinitely. However, in practical circuits, the electric energy is lost due to the parasitic resistance of the inductor coils and the capacitor dielectric. As a result, the amplitude of the oscillations reduces, thereby creating a damping effect. One of the easiest ways to overcome this damping effect is to take a proportion of output, amplify it, and feed it back to the input. For this purpose, usually a bipolar junction transistor (BJT) or a metal-oxide-semiconductor field-effect transistor (MOSFET) is used.

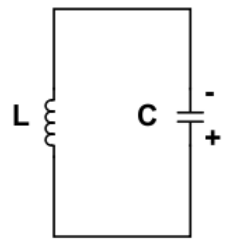


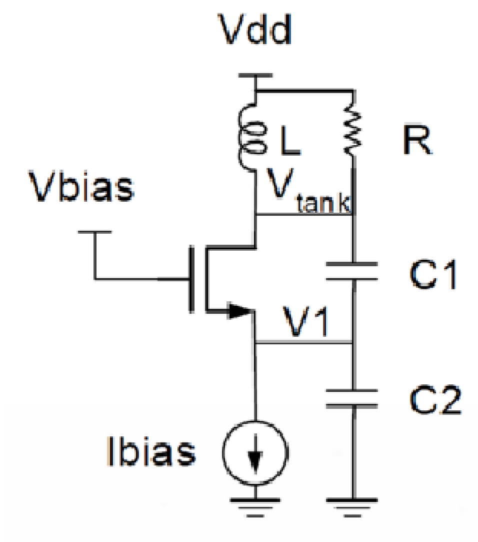
Figure 1: LC Tank Circuit

Colpitts Oscillator

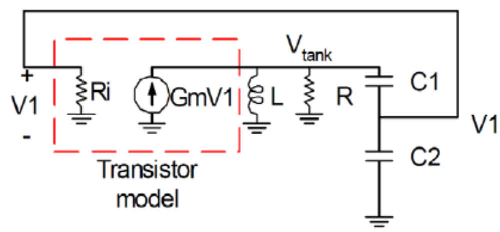
During this workshop, we will analyse the performance of the Colpitts Oscillator oscillator. Figures 2 (a) and (b) represent the circuit diagram and the simplified linear model of the Colpitts Oscillator. Using eqn (1) and analysing the linear model given in Figure 2 (b), the oscillating frequency, f, and the minimum transistor gain, g_m required to start oscillation can be represented as follows (derivations of these equations are given in Lecture 8):

$$f = \frac{1}{2\pi\sqrt{L\left(\frac{C_1 C_2}{C_1 + C_2}\right)}} \tag{3}$$

$$g_m > \frac{1}{R\left(n - n^2\right)} \tag{4}$$



(a) Colpitts Oscillator Circuit



(b) Simplified Linear Model for Colpitts Oscillator

Figure 2: Colpitts Oscillator Analysis

Colpitts Oscillator Simulation

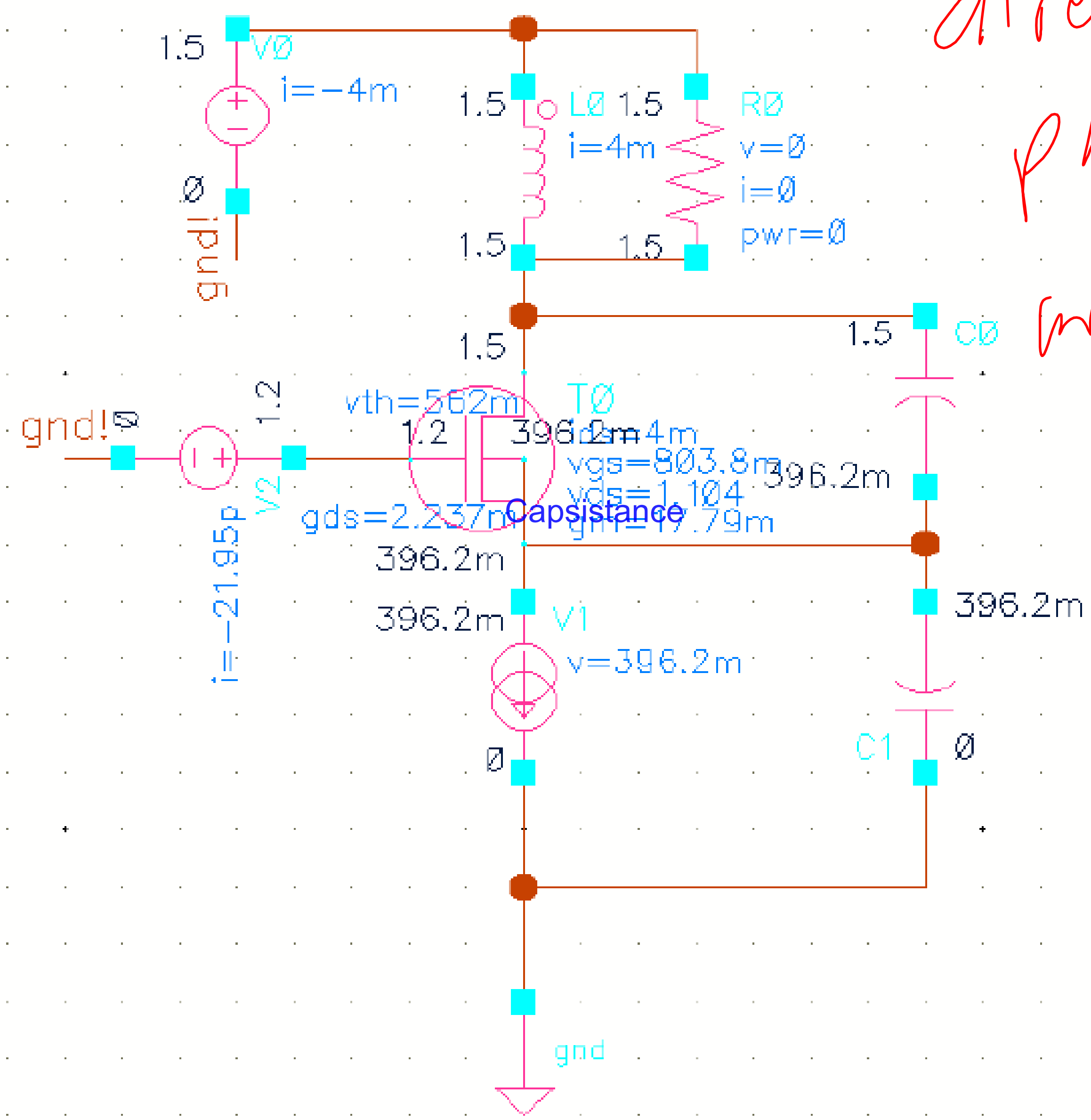
Consider the Colpitts Oscilattor circuit shown in Figure 3, where L = 1 nH, C_1 = C_2 = 24 pF, and R = 500 Ω

Tasks

- Calculate the minimum gain, g_m, required to start the oscillations.
- Calculate the frequency of oscillations, f.
- Implement the circuit shown in Figure 3 in Cadence with a proper sized transistor and bias this circuit.
- Run a transient simulation with maxstep < 0.1 / f and observe the output signal.
- Compare the simulated and calculated values of f

make drain current and source current equal

direct plot



mean

form

source current large, decrease; Drain current large, increase.

Figure 3: Colpitts Oscillator Circuit

Cadence Simulation 2: Input Matching of Cascode Amplifier at 1.5 GHz

Consider the cascode amplifier circuit shown in Figure 4 with the following parameters.
$W = W_{TO} = W_{T2} = 1\text{mm}$, $L = L_{TO} = L_{T2} = 2\text{um}$, $V_{DD} = 1.5$ V, $L = 1$ nH

Tasks

- Build the circuit shown in Figure 4 in Cadence
- Bias the transistor $T0$ at 800mV
- Simulate S-Parameter of the input port. T? S11?
- Based on the S-parameters, design an input matching circuit using L-matching for this input port and verify it with simulations. Z11 Z22

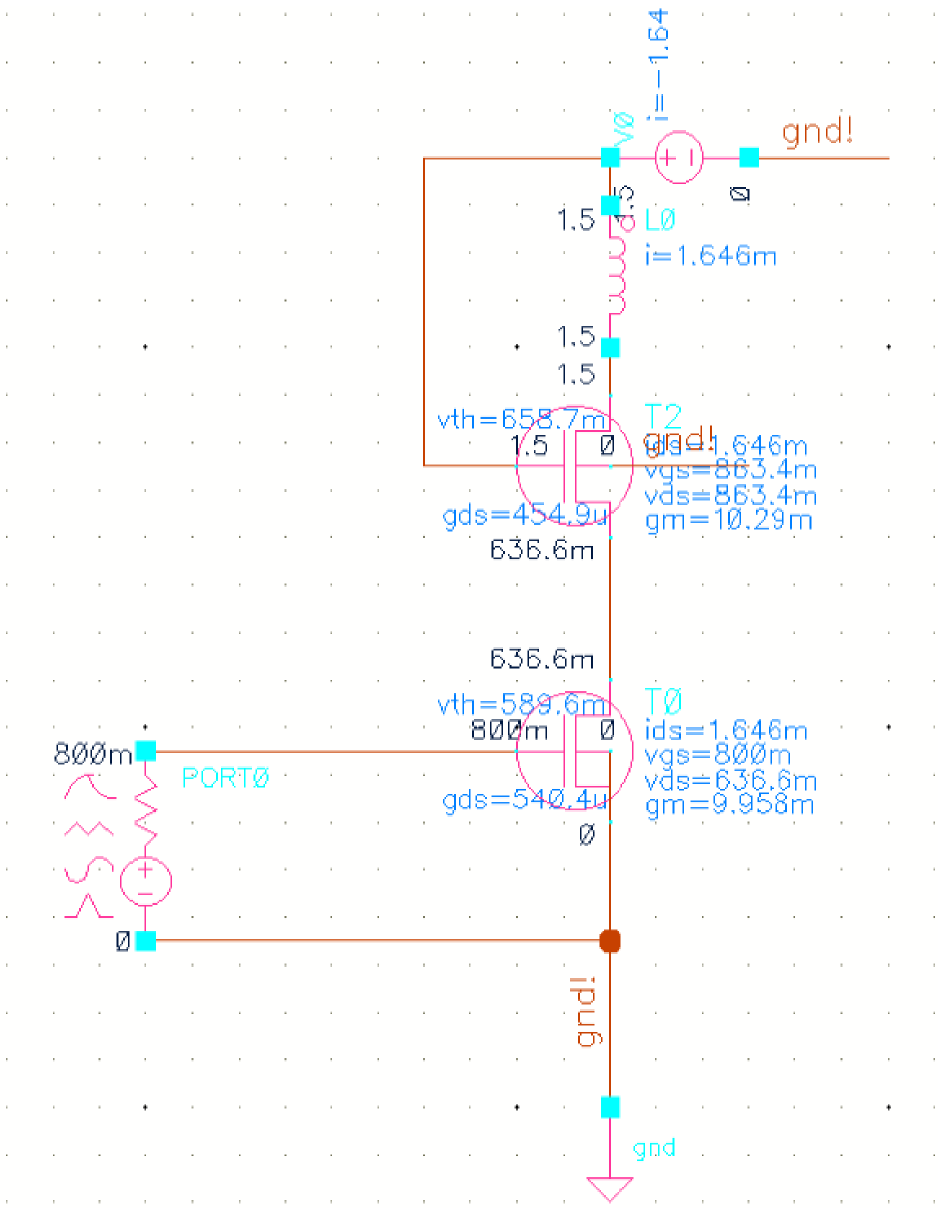


Figure 4: Cascode Amplifier Circuit