Assignment 3

Sanket Kansara
101026295

Design steps

Design of a voltage controlled negative gm oscillator using 130nm CMOS technology by IBM.

Topology used

Voltage controlled oscillator with cross coupled transistor, having capacitance and inductance to have it oscillate at particular frequency. The differential voltage across two transistor will be buffered first and then supplied to a load of 500Ω.

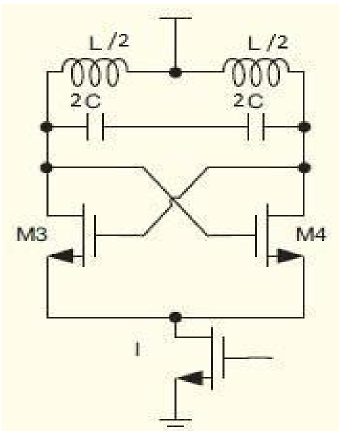

Figure 1 Bias current mode negative transconductance(gm) oscillator

As can be seen form the figure 1, we are going to design Colpitts oscillator with NMOS only. The Colpitts Oscillator consists of a parallel LC resonator tank circuit whose feedback is achieved by connecting two NMOS transistor back to back as shown in the figure.

Targeted specification

The oscillator was designed meet following specifications.

Table 1 Targeted specification for VCO

Design parameter	Targeted specification
Operating frequency	7.495 GHz
Output amplitude	≥ 300 $mV_{p,diff}$
Tuning range	300 MHz
Phase noise	≤ -107.51 dBc/Hz at 1 MHz offset

Design calculations

The output differential voltage required at 500 Ω is 300 mV_p. Considering losses in buffer circuit the differential voltage across the tank circuit is designed to be 700 mV_p.

$$V_{tank} = \frac{2}{\pi} I_{bias} Q\, \omega\, L = 0.7\, V$$

Assuming 1 mA of bias current and Q factor of 15, I have calculated tank inductance to be,

$$L = 1.556x10^{-9}\, H$$

The tank inductance was split into two series **778 pH** inductors. As shown above in fig 1.

Characterizing Inductors

The characterization has been done with targeted inductance 778 pH and quality factor Q > 15 , which we have assumed for the calculation of tank inductance.

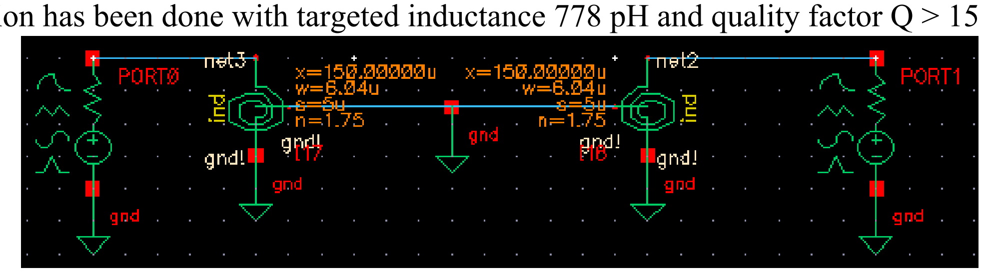

Figure 2 Testbench used for characterization of the inductor

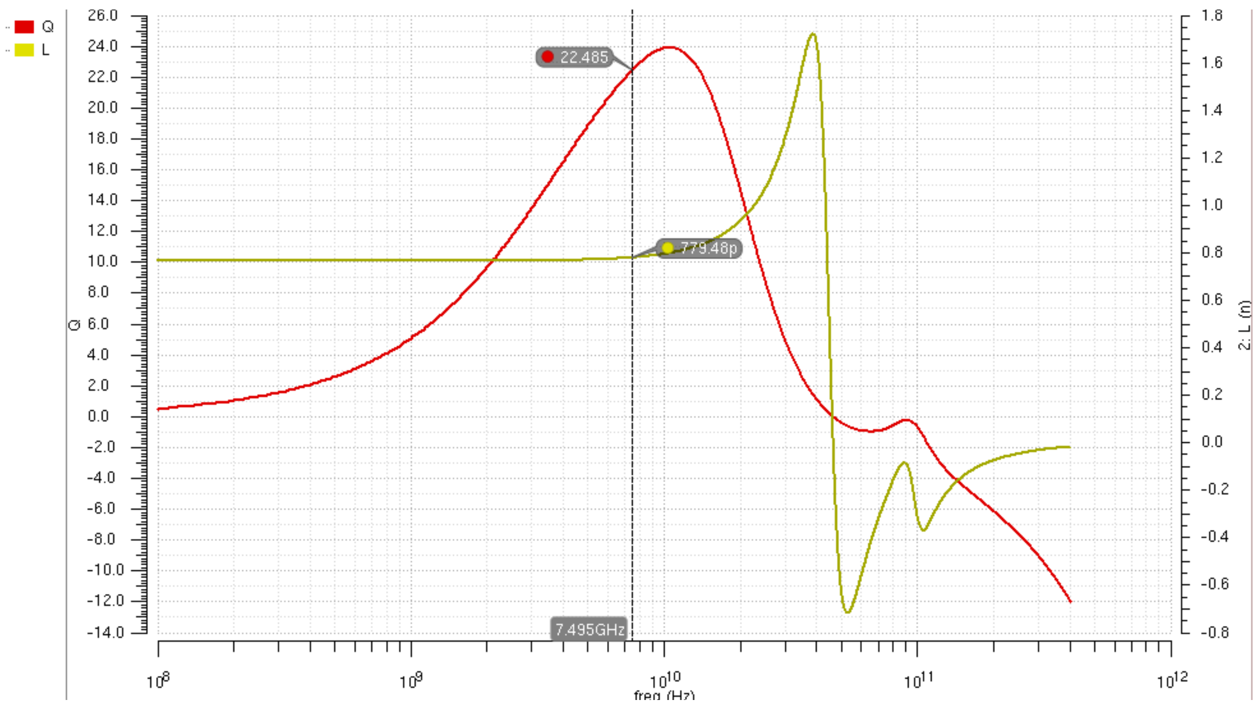

Figure 3 Frequency vs inductance (778p) and quality factor (Q>15) of the inductor

Table 2 Properties of cmrf8sf library inductor

Inductance	779.48 pH	Q	22.48
Outer dimension	150 µm	Number of turns	1.75
Metal width	6.04 µm	Max turns	5.5

<u>Capacitor calculation</u>

The capacitance required per side can be calculated as follows,

$$C = \frac{1}{L\,\omega^2}$$

Where $\omega = \frac{1}{2\pi f}$,

The oscillator is desired to be tunable for 300 MHz frequency range. (150 MHz above and below the nominal frequency 7.495 GHz). Substitute value of frequency equal to 7.345 GHz for Cmax and 7.645 GHz for Cmin.

$$Cmax = \frac{1}{0.778x10^{-9}\left(2\pi\, 7.345x10^{9}\right)^2} = 603.5\ x\ 10^{-15}F$$

$$Cmin = \frac{1}{0.778x10^{-9}\left(2\pi\, 7.645x10^{9}\right)^2} = 557.06\ x\ 10^{-15}F$$

Now, we are going to split these capacitors in fix and variable.

$$\frac{Cmax}{Cmin} = \frac{C_{fix}+C_{max,var}}{C_{fix}+C_{min,var}} = 1.083$$

After some simulation for varactor characterization I have observed that Cgate at control voltage (Vc) equal to 0 and 1.2 V is related with ratio of 1.43 hence I have selected my fix capacitance accordingly.

$$Cmax = C_{fix} + C_{max,var} = 459\, fF + 144.5\, fF = 603.5\, fF$$

$$Cmin = C_{fix} + C_{min,var} = 459\, fF + 98.06\, fF = 557.06\, fF$$

<u>Varactor characterization</u>

There are two type of varactors available in cmrf8fs library. NCAP(regular oxide thickness) and DGNCAP(thick oxide). Here, NCAP is used since it has a wider tuning range. The varactors are both characterized by both gate and well sides.

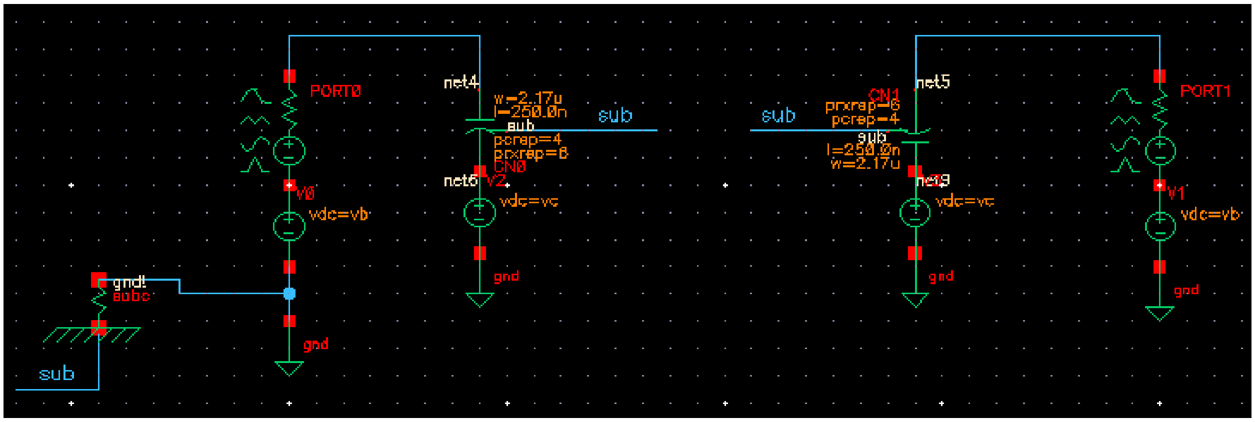

Figure 4 Test bench used for NCAP varactor characterization