Tutorial 4: Oscillator

Problem 1

Suppose $H(s)$ in the negative feedback system shown below satisfies the following conditions at a frequency of ω_1: $|H(s)| = 1$, and $\angle H(s) = 170°$.

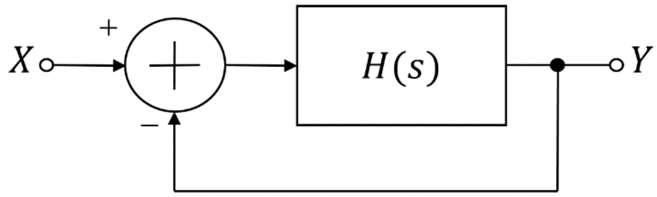


Fig. 1. Negative feedback system

Explain what happens to the phase and the amplitude of the output signal.

Problem 2

Prove that the series combination of the two tanks in Fig. 2(a) can be replaced by one tank as shown in Fig. 2(b).

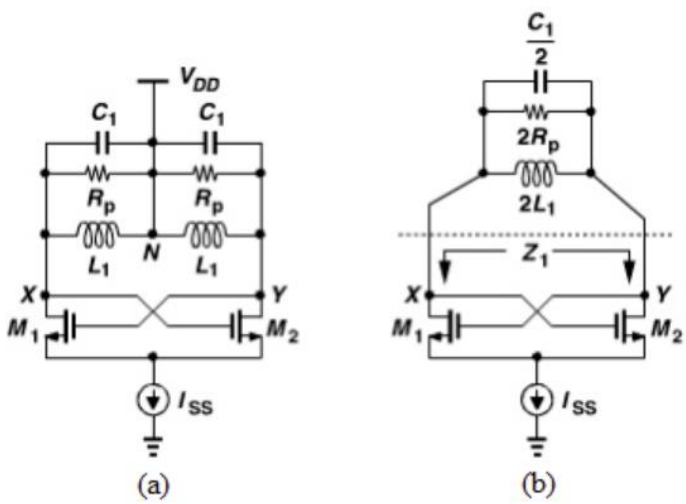


Fig. 2 (a) Cross-coupled oscillator. (b) with tanks merged

Problem 3

A negative resistance LC oscillator is shown in Fig. 3. The component values are L=5 nH, C = 2.5 pF, Inductor Q = 5 and $\mu_n C_{ox}$ = 110 μA/V^2.

a) Calculate the frequency of oscillation, without and with losses in the inductor.
b) Calculate the value of negative resistance provided by the cross-coupled NMOS transistor pair to support oscillation.
c) What is the W/L ratio of $M1$ and $M2$ to achieve the required negative resistance.

d) To cover 40 MHz frequency band, the RFIC-designer would like to use a varactor, replacing the C in the schematic with a Cvar, a varactor with a tuning range from Cmin to Cmax. Calculate the tuning range of the capacitor (%). Is the required tuning range possible to achieve with a conventional CMOS varactor?

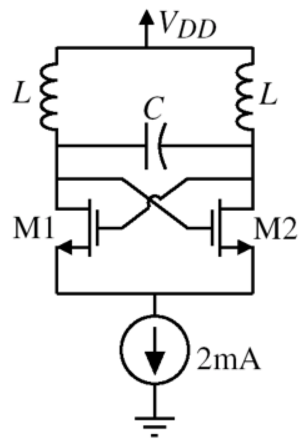


Fig. 3. Negative resistance LC oscillator

Problem 4

A single-transistor inductor-feedback oscillator is shown in Fig. 4.

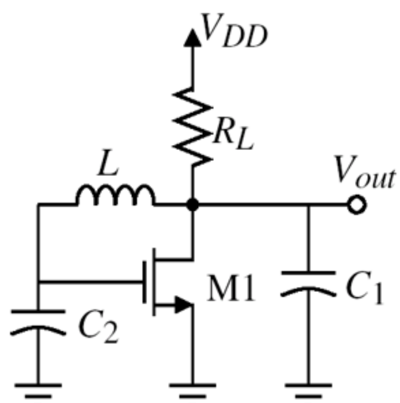
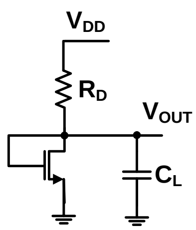


Fig. 4. Single-transistor inductor-feedback oscillator

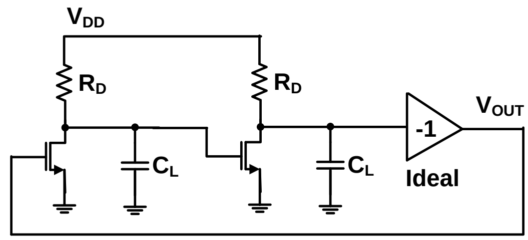
Find an expression for the frequency of oscillation and the value of $g_m R_L$ necessary for oscillation. Assume that output resistance of the transistor is negligible.

Homework 1

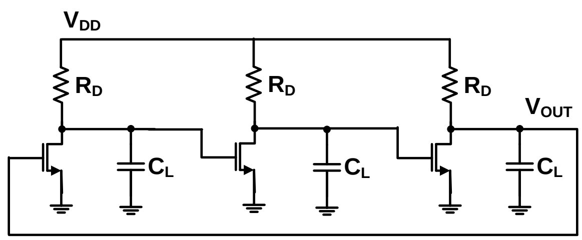
Which of the following (a), (b), and (c) circuit oscillates? State the reason in terms of frequency dependent phase shift and DC phase shift.



(a)



(b)



(c)

Answer:

(a) DC phase shift = 180° (frequency → 0)

Open loop circuit contains one pole

=> Frequency dependent phase shift = 90° (at frequency → ∞)

Total phase shift = 90° + 180° = 270° => No oscillation.

(b) DC phase shift = 180° (frequency → 0)

Open loop circuit contains two poles

=> Frequency dependent phase shift = 90° + 90° = 180° (at frequency → ∞)

Total phase shift = 180° + 180° = 360°

But as frequency → ∞ the loop gain vanishes => No oscillation.

(c) DC phase shift = 180° (frequency → 0)

Open loop circuit contains three poles

=> Frequency dependent phase shift = 90° + 90° + 90° = 270° (at frequency → ∞)

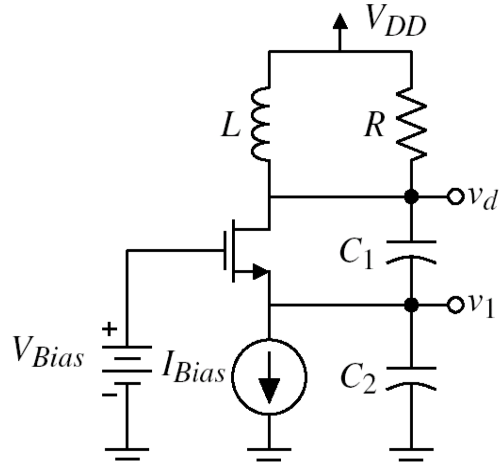
Total phase shift = 180° + 270° = 450° or 90°

However at $f = f_{p1,2,3} < \infty$, where f_p is the cut-off frequency of a stage, the frequency dependent phase shift = 45° + 45° + 45° = 135°

Therefore for some $f_p < f < \infty$ the circuit may oscillate with a sufficient loop gain.

Homework 2

A Colpitts oscillator is shown in figure below. Find the oscillation frequency, ω_{osc} and the value of g_m necessary for oscillation, in terms of L, C_1, C_2 and R. Neglect channel-length modulation and the body effect.



Answer:

$$\omega_0 = \sqrt{\frac{1}{L\frac{C_1C_2}{C_1+C_2}} + \frac{1}{R\frac{C_1C_2}{g_m}}}$$

$$g_m R_L = \left(\frac{C_1+C_2}{C_1C_2L} + \frac{g_m}{C_1C_2R}\right)L(C_1+C_2)$$

$$g_m = \frac{R(C_1+C_2)^2}{R^2C_1C_2 - L(C_1+C_2)}$$