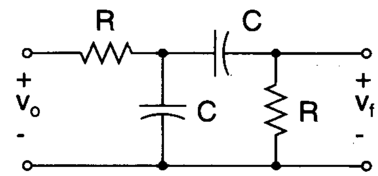
Electronics II - Extra Practice Problems - Sinusoidal Oscillators

1. The following circuit is used as the phase-shifting network for a two-stage FET oscillator. Find the circuit's beta, $\beta(s) = \frac{v_f}{v_o}$. Determine the frequency of oscillation and the gain required from the amplifier. (30 points)



2. Design a 680kHz Wein-bridge oscillator. Use an ideal op-amp as your active element.

3. For the oscilator circuit shown below, the two transistors have $g_m = 1.6mA/V$. Each part below is 5 points.

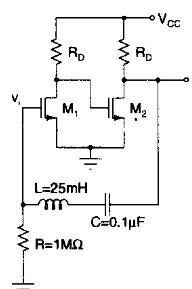
   (a) Draw a diagram of the phase shift network.

   (b) Find $\beta(s) = \frac{v_i}{v_o}$ from the diagram drawn in part (a).

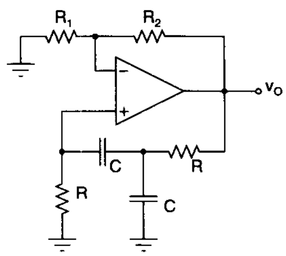
   (c) Determine the loop gain, $A(s)\beta(s)$. HINT: THE GAIN WILL DEPEND ON THE PHASE SHIFT NETWORK.

   (d) Apply the Barkhausen Criterion to find the frequency of oscillation.

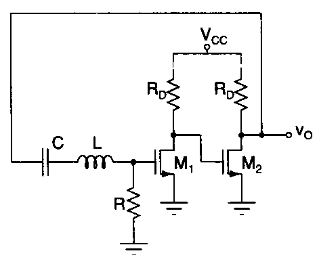
   (e) Find the minimum value of R_D that would satisfy the Barkhausen Criterion.



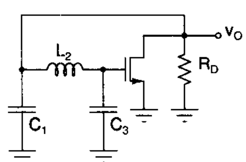
4. For the oscillator shown below, derive an expression for the frequency of oscillation in terms of R and C. What minimum value of $\frac{R_2}{R_1}$ is required for oscillations to be maintained?



5. For the oscillator shown below, derive an expression for the frequency of oscillation in terms of R, L and C. Find an expression, in terms of g_m, R_D and R, that must be satisfied in order to have sustained oscillations.

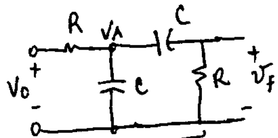


6. For the Colpitts oscillator shown below, find values for L_2, C_3 and R_D appropriate to produce sustained oscillations at $100kHz$ if $C_1 = 10nF$. Use $g_m = 1mA/V$.



Extra Practice Problems - Sinusoidal Oscillators

1)



$$v_f = \frac{R}{R + \frac{1}{sC}} V_A = \frac{sCR}{sCR+1} V_A$$

$$Z_{eq} = \frac{\left(R + \frac{1}{sC}\right)\left(\frac{1}{sC}\right)}{R + \frac{2}{sC}} = \frac{1}{sC} \frac{sCR+1}{sCR+2}$$

$$\frac{V_A}{V_o} = \frac{Z_{eq}}{Z_{eq} + R} = \frac{sCR+1}{sC(sCR+2)\left(R + \frac{sCR+1}{sC(sCR+2)}\right)}$$

$$= \frac{sCR+1}{s^2C^2R^2 + 2sCR + sCR + 1} = \frac{sCR+1}{s^2C^2R^2 + 3sCR + 1}$$

$$\beta = \frac{V_f}{V_o} = \frac{V_f}{V_A}\frac{V_A}{V_o} = \frac{sCR}{s^2C^2R^2 + 3sCR + 1}$$

To satisfy the Barkhousen Criterion: $s^2C^2R^2 + 1 = 0$

$-\omega^2C^2R^2 + 1 = 0 \Rightarrow \boxed{\omega_r = \frac{1}{RC}}$

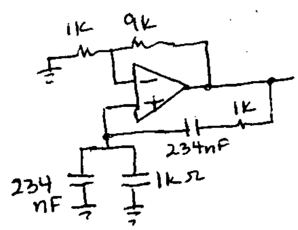
at $\omega = \omega_r$, $\beta = \frac{1}{3}$; $\therefore$ $\boxed{\text{amplifier gain} \geq 3}$

2) From book/class notes, $\omega = \frac{1}{RC}$; $1 + \frac{R_2}{R_1} \geq 3$

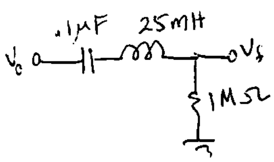
for $\omega = 2\pi \times 680\text{ kHz}$, let $R = 1\text{k}\Omega$; $C = 0.234\,\mu F$

Set gain to 10 $\quad \frac{R_2}{R_1} = 9$; let $R_1 = 1\text{k}\Omega$, $R_2 = 9\text{k}\Omega$

Diagram is



3) (a)



b) $$\beta = \frac{1M\Omega}{1M\Omega + \frac{1}{(.1\mu F)s} + (25mH)s}$$

$$= \frac{.1s}{2.5\times10^{-9}s^2 + .1s + 1}$$

$$= \frac{4\times10^7 s}{s^2 + (4\times10^7)s + 40\times10^7} = \frac{sCR}{LCs^2 + sCR + 1}$$

c) $Z_p = R + sL + \frac{1}{sC}$ $\quad Z_D = R_D \| Z_p = \dfrac{R_D\left(R + sL + \frac{1}{sC}\right)}{R_D + R + sL + \frac{1}{sC}}$

$$Z_D = \frac{R_D(s^2LC + sCR + 1)}{s^2LC + (R+R_D)s + 1}$$

$$\text{gain} = (-g_m R_D)(-g_m Z_D) = g_m^2 R_D^2 \frac{s^2LC + sCR + 1}{s^2LC + (R+R_D)s + 1}$$

$$\text{gain} \times \beta = g_m^2 R_D^2 \frac{sRC}{s^2LC + (R+R_D)s + 1}$$

d) $s^2LC + 1 = 0$; $-\omega_r^2 LC + 1 = 0$; $\omega_r = \frac{1}{\sqrt{LC}}$

$$\omega_r = \frac{1}{\sqrt{1\,mH \times .1\,\mu F}} = 100{,}000 \text{ r/s}$$

e) gain $\times \beta$ at $\omega = \omega_r$ $= g_m^2 R_D^2 \dfrac{R}{R+R_D} > 1$

$$(1.6\times10^{-3})^2 R_D^2 \frac{10^6}{10^6 + R_D} > 1$$

$$2.56 R_D^2 - R_D - 10^6 > 0$$

$$R_D = \frac{+1 \pm \sqrt{1 - (2.56)(-10^6)}}{2(2.56)} \geq \boxed{313\,\Omega}$$

4) Feedback network is the same than problem's 1.

$\therefore$ $1 + \frac{R_2}{R_1} \geq 1 \rightarrow R_2/R_1 \geq 2$

5) Same as problem. 3.

6) $\beta = \dfrac{\frac{1}{sC_3}}{sL_2 + \frac{1}{sC_3}} = \dfrac{1}{s^2L_2C_3 + 1}$

$$Z_D = R_D \| \frac{1}{sC_1} \| \left(sL_2 + \frac{1}{sC_3}\right)$$

$$= \frac{1}{\frac{1}{R_D} + sC_1 + \frac{sC_3}{s^2L_2C_3 + 1}}$$

$$\rightarrow Z_D = \frac{s^2L_2C_3 + 1}{\left(\frac{1}{R_D} + sC_1\right)(s^2L_2C_3 + 1) + sC_3}$$

$$= \frac{R_D(s^2L_2C_3 + 1)}{(sC_1R_D + 1)(s^2L_2C_3 + 1) + sR_DC_3}$$

$$= \frac{R_D(s^2L_2C_3 + 1)}{s^3R_DL_2C_1C_3 + sC_1R_D + s^2L_2C_3 + sR_DC_3}$$

$$Z_D = \frac{R_D(s^2L_2C_3 + 1)}{s^3R_DL_2C_1C_3 + sR_D(C_1 + C_3) + s^2L_2C_3 + 1}$$

$$\text{gain} = -g_m Z_D = \frac{-g_m R_D (s^2 L_2 C_3 + 1)}{s^3 R_D L_2 C_1 C_3 + s^2 L_2 C_3 + s R_D (C_1 + C_3) + 1}$$

$$\beta \times \text{gain} = \frac{-g_m R_D}{s^3 R_D L_2 C_1 C_3 + s^2 L_2 C_3 + s R_D (C_1 + C_3) + 1}$$

$$s^2 \cancel{s^3} R_D L_2 C_1 C_3 + \cancel{s} R_D (C_1 + C_3) = 0$$

$$+\omega_r^2 R_D L_2 C_1 C_3 = R_D (C_1 + C_3)$$

$$\omega_r = \sqrt{\frac{C_1 + C_3}{R_D L_2 C_3 C_1}}$$

$$C_1 = 10nF$$

$$\omega_r = \sqrt{\frac{10nF + C_3}{R_D L_2 C_3 (10nF)}}$$

set $C_3 = 1nF$

$$\omega_r = \sqrt{\frac{11nF}{10^{-17} R_D L_2}} = 10^5$$

$$\frac{10^{-17} R_D L_2}{11 \times 10^{-9}} = 10^{-10}$$

$$R_D L_2 = \frac{11 \times 10^{-9} \times 10^{-10}}{10^{-17}} = .11$$

set $L_2 = 1mH$

$$\boxed{R_D = 110\,\Omega}$$