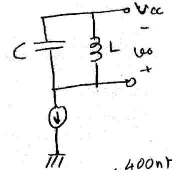
Question 1) (20 points)



400nH

The tank circuit which is shown above is to be used at a high frequency design. The self resonance of the inductor is 100 MHz. Please answer the following:

a) (10 points) Can you make a 200 MHz resonant tank circuit using this inductor? If so, calculate the value of the capacitor to obtain the resonance frequency, explain your answer

b) (10 points) Can you make a 50 MHz resonant tank circuit using this inductor? If so, calculate the value of the capacitor to obtain the resonance frequency, explain your answer

a-) No, because the inductor acts as a capacitor above its parallel resonance frequency

b-) Yes, the equivalent model of the inductor is w_0 at self resonance is 628.3×10^{6} rad/sec

L = 400nH  $C_S = \frac{1}{w_0^2 L} = \frac{1}{(2\pi\times100\times10^6)^2\times400\times10^{-9}}$

$= 6.333\times10^{-12}$ F

Four times C_L is needed to lower the parallel resonance to its half $\Rightarrow$ The total parallel capacitance $C_T = 25.33$ pF

The capacitance needed over the C_S is

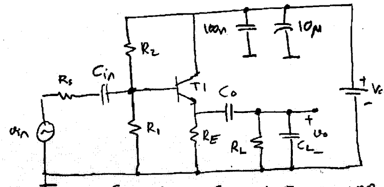
$\boxed{25.33 - 6.33 = 19\text{pF}}$

a-)

$C_{be} = 4$
$C_{bc} = 3$
$C_L = 4$
$\Sigma = 4$

Question 2) (30 points)

b-) bias 3
Cin 4
Cout 4
Σ 4

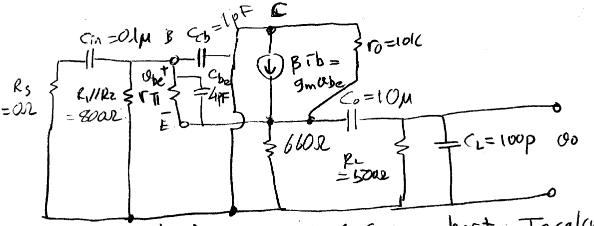


$r_o = 10K$ $C_{be} = 4pF$ $C_{bc} = 1pF$ $\beta = 100$

For the circuit given above, $R_s=0\Omega$, $R_1=1k\Omega$, $R_2=4k\Omega$, $R_E=660\Omega$, $V\gamma=0.7V$, $C_{in}=100nF$, $C_o=10\mu F$, $R_L=500\ \Omega$ and $C_L=100pF$. ~~Assume that $R_1 // R_2 \ll R_s$.~~

a) (15 points) Estimate the higher 3 dB cut-off frequency by the method of open-circuit time constants.

b) (15 points) Estimate the lower 3 dB cut-off frequency by the method of short-circuit time constants.



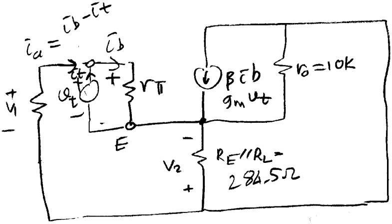
a-) At high frequencies Cin & Co are short. To calculate Rbe, open circuit the high-frequency capacitors, and put v_T across B and E

$$I_E = \left(15 \times \frac{1}{1+4} - V_\gamma\right) \Big/ \left(660 \,//\, \frac{1\times 4}{5(\beta+1)}\right) = \frac{3-0.7}{660+8} = \frac{2.3V}{668\Omega}$$

$= 3.44\ mA$

$$\frac{1}{g_m} = \frac{26}{3.44} = 7.56\ \Omega \qquad r_\pi = 756\Omega = \frac{\beta}{g_m}$$

$R_s = 0\Omega // 3143\Omega$
$= 0\Omega$



$$R_E' = R_E // R_L // r_o = 276.6\,\Omega$$

$i_a = i_b - i_t \qquad v_t = i_b r_\pi = V_1 + V_2 = -i_a R_s - (\beta+1) i_b R_E' + i_t R_E'$

$$v_t = i_b r_\pi = -i_b R_s + i_t R_s - (\beta+1) i_b R_E' + i_t R_E'$$

$$i_b = (r_\pi + R_s + (\beta+1)R_E' = (R_s + R_E') i_t \Rightarrow i_b = \frac{R_s + R_E'}{r_\pi + R_s + (\beta+1)R_E'} i_t$$

$$R_{be} = \frac{v_t}{i_t} = \frac{i_b r_\pi}{i_t} = \frac{(R_s + R_E') r_\pi}{r_\pi + R_s + (\beta+1) R_E'} \frac{\cancel{i_t}}{\cancel{i_t}} = \frac{276.6 \times 756}{756 + 101 \times 276.6} = 7.3\Omega$$

$\tau_{be} = 7.3 \times 4 \times 10^{-12} = 29.2\,\text{psec} = 0.029\,\text{nsec}$

R_{cb} is a capacitor connected between base & the ground. Therefore it sees the amplifier input impedance in parallel with $R_s \Rightarrow 29.1\,\text{psec}$

$$R_{cb} = \underbrace{R_s // R_1 // R_2}_{0\Omega} // (r_\pi + (\beta+1)(R_E // R_L // r_o))$$

$$\Rightarrow R_{cb} = 0 \;\; // \underbrace{(756.8 + 101 \times 276.6)}_{\text{too large compared to } 0\Omega} \cong 0\Omega$$

$\tau_{bc} = 0\,\text{sec}$

(2-a) continued

C_L sees R_{CL}

$$R_{CL} = r_o // R_L // R_E // \left(\underbrace{\frac{r_\pi}{(\beta+1)}}_{\cong 1/g_m} + \underbrace{\frac{R_s // R_1 // R_2}{\beta+1}}_{\cong 0} \right)$$

$$= (276.6\Omega) // \left(\frac{1}{g_m} + \frac{0}{101} \right) = 276.6 // \left(\frac{26}{3.44} + 0 \right)$$

$$= 276.6 // 7.5 \qquad = 276.6 // 7.5 \cong 7.3\Omega$$

$$\approx \left(\frac{1}{g_m} + \frac{R_s}{\beta+1} \right)$$

$$\tau_{CL} = 7.3\Omega \times 100 \times 10^{-12} = 730\,psec = 0.730\,nsec$$

$$\Sigma \tau = \tau_{be} + \tau_{cb} + \tau_{CL} = 0.029\,nsec + 0 + 0.73\,nsec)$$

$0.759\,nsec$

$w_{3dB} = 1317$ Mrad/sec

$f_{3dB} = 209.7$ MHz

(2-b)

b-) $R_{C_{in}} = R_s + (r_\pi + (\beta+1)(R_E // r_o // R_L)) // \underbrace{R_1 // R_2}_{800\Omega}$

$= 0 + 756 + 104 \times 276) // 800$

$\rightarrow 28692 // 800 = 778\Omega$

$R_s = 0$

$R_{Co} = R_E // r_o // \left(\frac{1}{g_m} + \frac{R_s}{\beta+1}\right) + R_L$

$660 // 10000 // 7.56 + 500) \simeq 507.6$

$\tau_{cin} = 778 \times 10^{-7} = 0.778 \times 10^{-4}$ sec

$\tau_{Co} = 507.6 \times 10^{-5}$ sec

$\frac{1}{\tau_{co}} + \frac{1}{\tau_{cin}} =$ 197 rad/sec + 12853 rad/sec = 13050 rad/sec

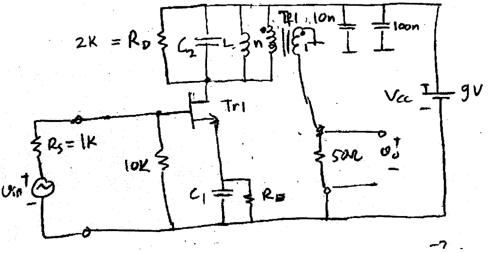
$f_{3dB} = 2077$ Hz

2-a) alternative solution

$R_{be} = \frac{R_E' r_\pi}{r_\pi + (\beta+1)R_E'}$ for $R_s = 0$

$= \frac{1}{\frac{\cancel{r_\pi}}{\cancel{r_\pi} R_E'} + \frac{\beta \cancel{R_E'}}{\cancel{R_E'} r_\pi} + \frac{\cancel{R_E'}}{\cancel{R_E'} r_\pi}} = \frac{1}{\frac{1}{R_E'} + g_m + \frac{1}{r_\pi}}$

Question 3)   (26 points)



At the tuned circuit given above, C_{gd}=1pF, C_{gs}=3pF, g_m=10mS, C_1=100nF, R_E=120Ω. Design the tuned circuit by:

a) (6 points) By finding the transformer ratio, n (T_{fl} is an ideal transformer), to present matched impedance to the drain of the tank circuit.
b) (6 points) By choosing C_2 such that it is 3 times the reflected miller capacitance to the drain,
c) (6 points) By choosing L to oparate at 40 MHz,
d) (8 points) Verify your design by calculating the 3dB BW of the gate circuit? Comment on the result.

a-) $n^2 50 = 2000 \Rightarrow n = \frac{200\cancel{0}}{5\cancel{0}} = 40 \Rightarrow n = 6.35$

b-) $C_{miller} = C_{gd} \times (1 + R_s g_m) = 1pF \times 11 = 11pF$

$C_2 = 3 \times 11pF = 33pF$

c-) $C_{total} = 33pF + 11pF = 44pF$

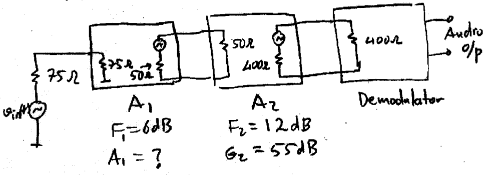
$L_3 = \frac{1}{w_o^2 C_{drain}} = \frac{1}{(2\pi \times 40 \times 10^6)^2 \times 44 \times 10^{-12}} = 360nH$

d-) $C_{in} = (1 + R_L g_m) C_{gd} + C_{gs} = 1pF(1+10) = 11pF + 3pF = 14pF$

$W_{3dB} = \frac{1}{14 \times 10^{-12} \times 1000\Omega} = 71.43\ Mrad/sec \Rightarrow f_{3dB} = 11.37MHz$

$\Rightarrow$ Input BW does not match the tank circuit design!

Question 4) (24 points)



Two amplifiers and a demodulator is cascaded as shown in the figure given above. Please answer the following:

a) (8 points) What should be the minimum gain of A1 so that the overall nosie figure of the cascaded amplifier is less than or equal to 7dB.

b) (8 points) Calculate the minimum signal level at the input of the cascaded amplifier in dBm, so that the cascaded amplifier can deliver a S/N ratio =12dB at its output to the demodulator if the bandwidth of the demodulator is 100kHz?

c) (8 points) What is the noise temperature of the cascaded amplifier?

a-) $7dB \Rightarrow 5$ times, $6dB \Rightarrow 4$ times, $12dB \Rightarrow 16$ times

$F_{12} = 5 = 4 + \frac{F_2 - 1}{G_1} \Rightarrow G_1 = \frac{15}{1} = 15$

$G_1 = 10 \times \log_{10} 15 = 11.76dB \simeq 11.7dB$

b-) $S_{required} = FkT_oB \times (S/N_{required})$

$= 5 \times 1.38 \times 10^{-23} \times 290 \times 10^5 \times 16 = 3.2 \times 10^{-14}$ Watts

$= 3.2 \times 10^{-11}$ mW

$= 10 \log_{10} 3.2 \times 10^{-11} = -104.9dBm$

c-) $(F-1)290 = T_n = (5-1) \times 290 = 4 \times 290 = 1160K$