

EEE 411/511 Final Exam
Solutions

Q1/1

Q.1

At class A, B and C type amplifiers the optimum load which must be seen by the transistor in order to deliver the required power with maximum efficiency, is the load which absorbs the power with peak amplitude voltage which nearly drives the transistor into saturation. That is $V_{\text{fundamental}} = V_{DD}$. Hence

$$48W = \frac{V_{DD}^2}{2R_{opt}} \Rightarrow R_{opt} = \frac{V_{DD}^2}{2 \times 48W} = \frac{12^2}{2 \times 48}$$

$$R_{opt} = 1.5 \Omega$$

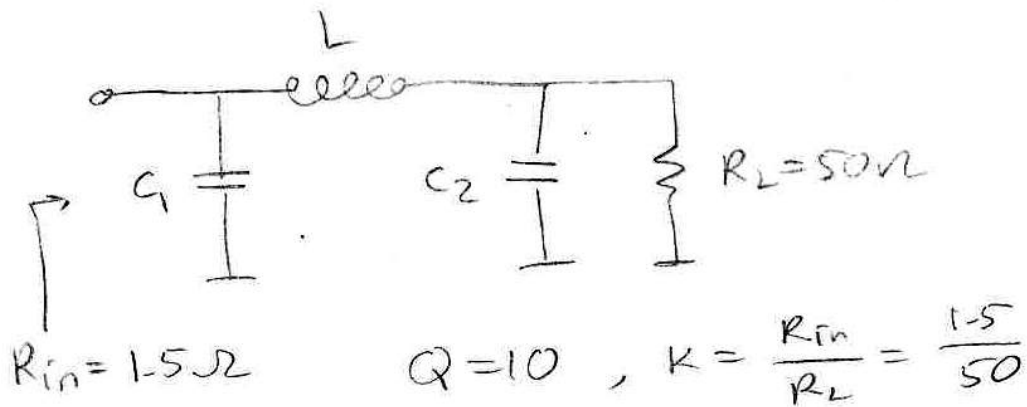
The Q of the match is given by

$$Q = \frac{f_0}{BW} = \frac{15.915}{1.5915} = 10$$

$$\omega = 2\pi \times 15.915 \times 10^6 = 99.99689 \text{ Mrad/sec} = 100 \text{ Mrad/sec}$$

$$K = \frac{R_{in}}{R_L} = \frac{1.5}{50} = 0.03$$

Q1/2



$$Q_R = \frac{[Q^2 K + 2K - K^2 - 1]^{1/2} - Q}{K - 1}$$

$$= 8.8299 \approx 8.83$$

$$Q_L \approx 1.17$$

$$X_{C_2} = \frac{R_L}{-Q_R} = -5.663 \Omega \quad C_2 = -\frac{1}{\omega X_{C_2}} = 1.766 \times 10^{-9} \text{ F}$$

$C_2 = 1.766 \text{ nF}$

$$X_{C_1} = \frac{R_{in}}{-Q_L} = -1.282 \Omega \quad C_1 = -\frac{1}{\omega X_{C_1}} = 7.8 \times 10^{-9} \text{ F}$$

$C_1 = 7.8 \text{ nF}$

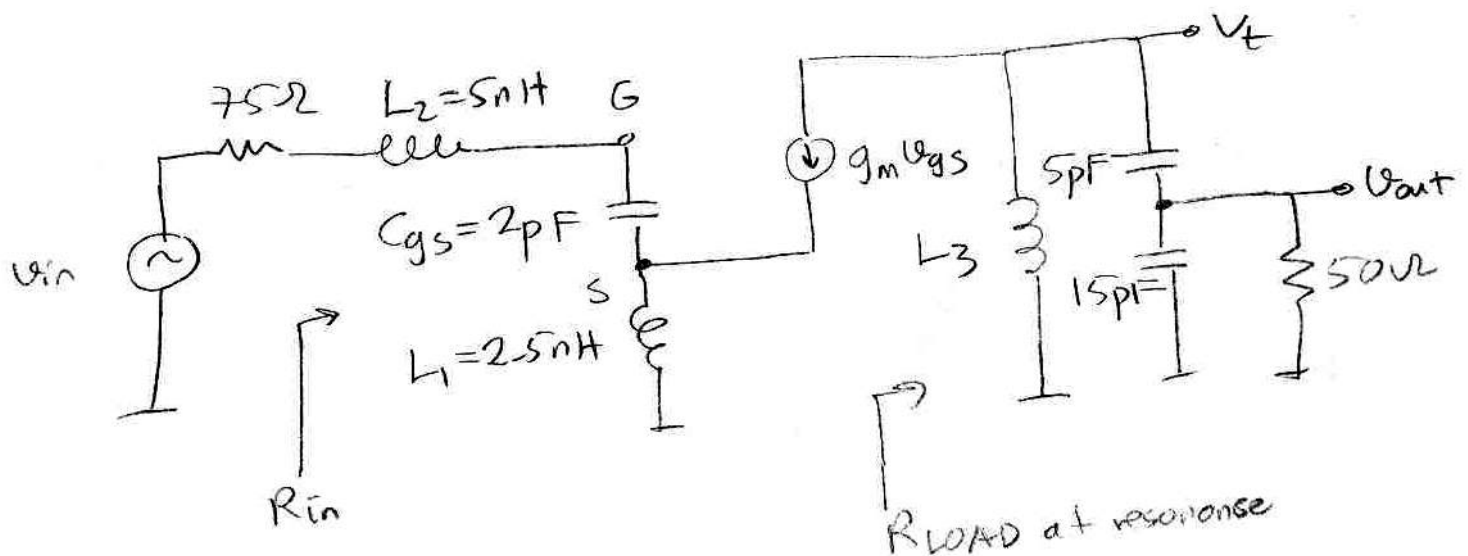
$$R_E = \frac{R_L}{(Q_R^2 + 1)} = \frac{50}{8.83^2 + 1} = 0.633 \Omega$$

$$X_L = Q R_E = 6.33 \Omega$$

$L = \frac{X_L}{\omega} = 6.33 \times 10^{-8} \text{ H} = 63.3 \times 10^{-9} \text{ H} = 63.3 \text{ nH}$

Q.2

This is an LNA with tuned drain load and inductive source degeneration. The A-C equivalent circuit is given by:



a-) The resonant frequency of the amplifier is given by:

$$\omega_0 = 2\pi f_0 = \frac{1}{\sqrt{(L_1 + L_2)C_{gs}}} = 8.1649 \times 10^9 \text{ rad/sec}$$

$$f_0 = 1.29949 \text{ GHz} \approx 1.3 \text{ GHz}$$

Q2/2

b-) L_3 is resonance with $C = \frac{5p \times 15p}{5p + 20p} = \frac{5 \times 3}{4} = \frac{15}{4} pF$

$$\omega^2 = \frac{1}{L_3 \frac{15}{4} \times 10^{-12}} \Rightarrow$$

$$L_3 = \frac{1}{(8.165 \times 10^9)^2 \times \frac{15}{4} \times 10^{-12}} = 3.9999 \times 10^{-9} H$$

$$L_3 = 4 \times 10^{-9} H = 4 nH$$

c-) R_{in} , the input impedance of the LNA at resonance is given by =

$$R_{in} = \frac{g_m}{C_{gs}} L_s = \frac{20 \times 10^{-3}}{2 \times 10^{-12}} \times 2.5 \times 10^{-9}$$

$$R_{in} = 25 \Omega$$

Therefore the gain of the circuit is given by

$$V_o = V_{in} \frac{25}{25 + 75} Q \times g_m \times R_{LOAD} \times n$$

where Q is the Q of the circuit composed of C_{gs} , L_1 & L_2 and

R_{LOAD} is the parallel loss resistance of the drain load and

n is the transformation ratio of the load capacitance transformer.

Q2/3

$$Q = \frac{\omega L}{R_{\text{series}}} = \frac{\omega (L_1 + L_2)}{25 \Omega}$$

$$= 100 \times 10^6 \times 7.5 \times 10^{-9} / 25 = 2.45$$

$$n = \frac{5 \text{ pF}}{(5 + 15) \text{ pF}} = \frac{5}{20} = \frac{1}{4}$$

$$n^2 = \frac{1}{16}$$

$$R_{\text{LOAD}} = \frac{50}{1/16} = 16 \times 50 = 800 \Omega$$

Therefore the gain

$$G = \frac{v_o}{v_{in}} = \frac{1}{4} \times 2.45 \times 20 \times 10^{-3} \times 800 / 4$$

$$G = 2.45$$

Q.3

a-) As in question 1, the optimum impedance to be seen by the transistor is given by

$$R_{opt} = \frac{V_{DD}^2}{2 \times P_{out}} = \frac{3.3^2}{2 \times 0.1W} = 54.45 \Omega$$

b-) Since we have two sinusoids of equal amplitude with different frequencies at the output of the transistor the total peak amplitude must not exceed V_{DD} in order to be able to operate without distortion. Therefore the peak amplitude of the each of the signals at the o/p is $V_{DD}/2$ which results in output powers for each of the signals as $\frac{100mW}{4}$ at the output. Adding them the total o/p power will be

$$P_o = \frac{100mW}{4} + \frac{100mW}{4} = \frac{100mW}{2} = 50mW$$

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Q. 4

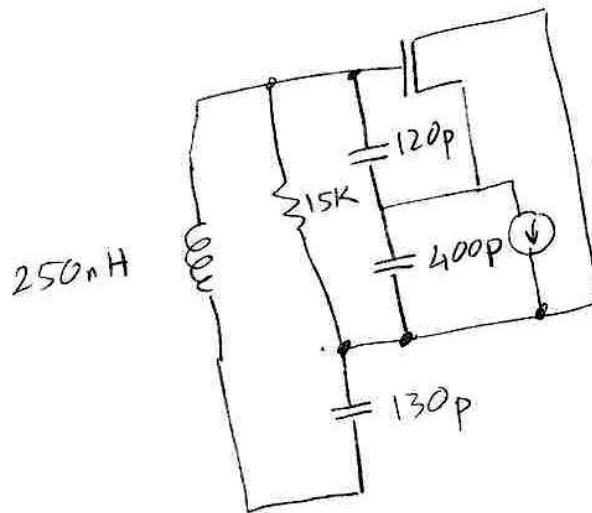
a-) 250 nH inductor resonates with the serial combination of the 3 capacitors. Hence
120 pF in series with 400 pF in series with 130 pF
= 53.98 pF

$$\Rightarrow \omega_0 = \frac{1}{\sqrt{53.98 \times 10^{-12} \times 250 \times 10^{-9}}} = 43.32 \times 2\pi \text{ rad/sec}$$

$$= 272.2 \text{ Mrad/sec}$$

$$f_0 = 43.32 \text{ MHz}$$

b-) The small signal equivalent circuit is



$$\frac{120 \times 400}{120 + 400} = 92.31 \text{ p}$$

$$n_1 = \frac{130}{130 + 92.31} = 0.5848$$

$$n_1^2 = 0.34196$$

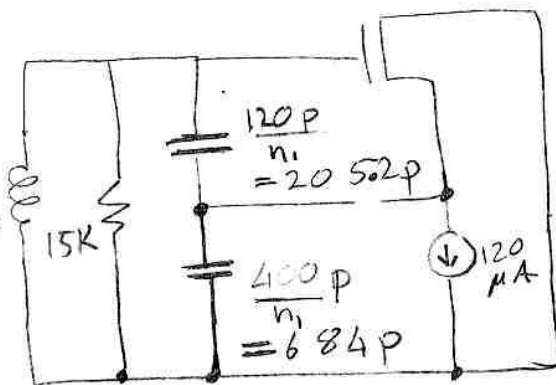
This circuit is equivalent to :

Q.4 (cont.)

$$250 \text{ nH} \times n_1$$

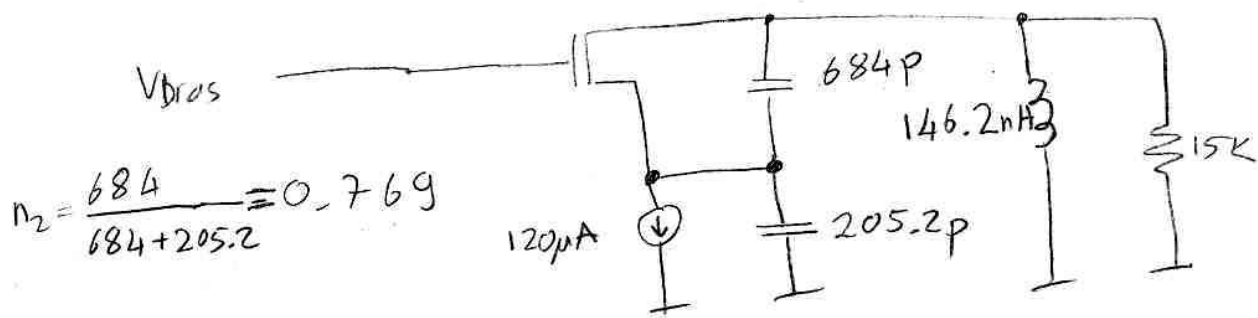
$$= 250 \times 0.5848 \text{ nH}$$

$$= 146.2 \text{ nH}$$



In this manner the Q of the tank circuit stays the same

If we ground the gate, for small signal operations the circuit becomes (since a D-C current source is open circuit to A-C. I can connect it anywhere as far as the brasing is properly done):



$$n_2 = \frac{684}{684 + 205.2} = 0.769$$

Since gate is grounded, I can connect all the leads connected to gate, to ground. Now I have arrived at a simple colpitts oscillator.

Now V_{tank} is given by

$$V_{\text{tank}} = 2 R I_{\text{BIAS}} (1 - n_2)$$

$$= 2 \times 15 \times 10^3 \times 120 \times 10^{-6} (1 - 0.231) = 0.8307$$

$$\approx 0.831 V_{\text{peak}}$$

Q.4 (cont.)

The voltage at the gate of the original circuit is the same as the voltage on the tank of the equivalent circuit. Therefore

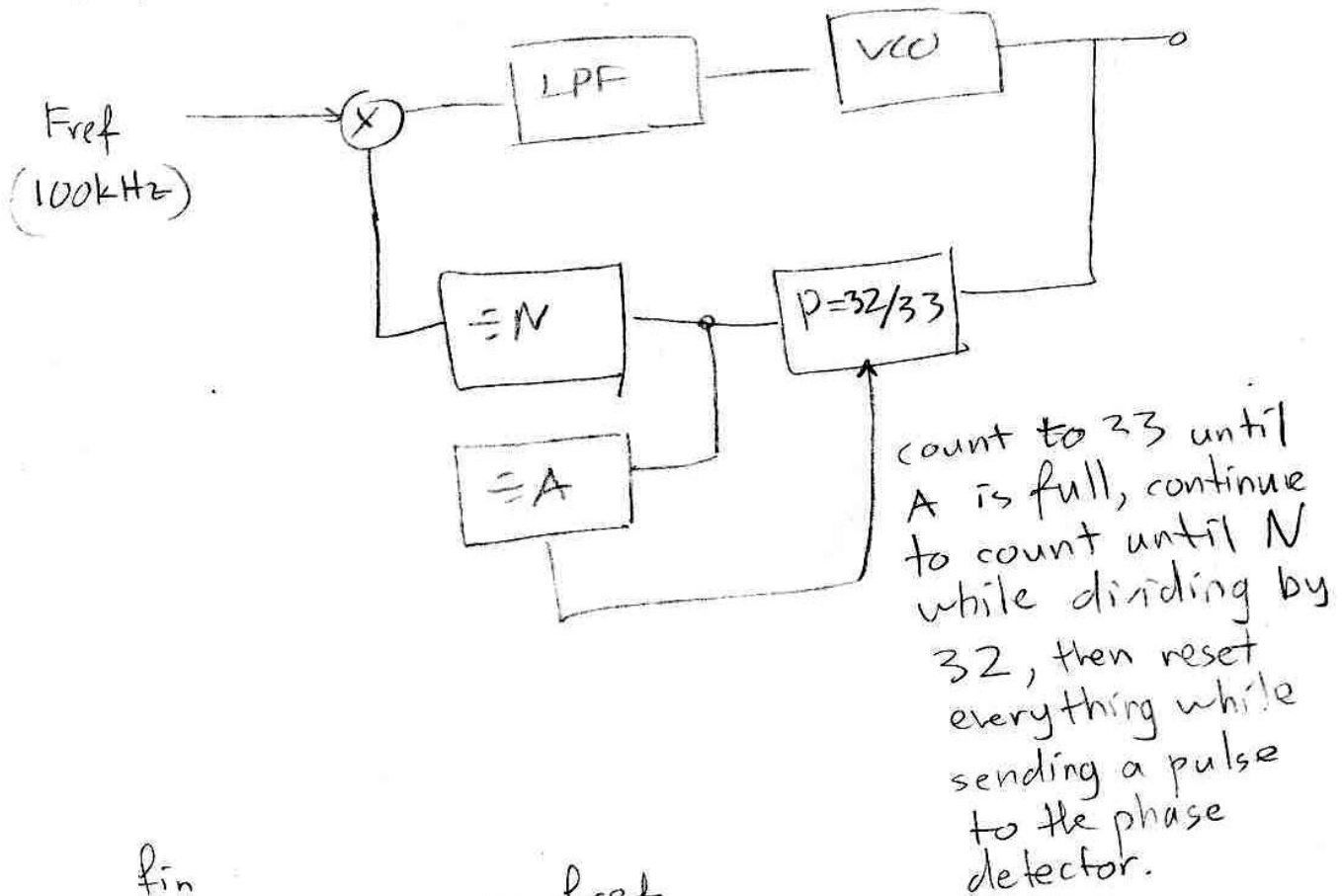
$$V_{\text{gate}} = V_{\text{tank}} = 0.831 V_{\text{peak}}$$

c-) The voltage on the inductor is readily found as

$$\frac{V_{\text{tank}}}{n_1} = \frac{0.831 V_p}{0.5848} = 1.4206 V_p$$

Q.5

a-)



$$\frac{f_{in}}{(32+A) + (N-A)32} = f_{ref}$$

$$\frac{f_{in}}{32A + A + 32N - 32A} = f_{ref}$$

$$\Rightarrow f_{ref} \times (32N + A) = f_{in} \quad A \leq N$$

Q5/2

b-) $f_{in} = 2455 \text{ MHz} = 0.1 \text{ MHz} (32N + A)$

$$\Rightarrow 24550 = 32N + A$$

One of the choices of N and A will be

$$\frac{24550}{32} = 767.1875$$

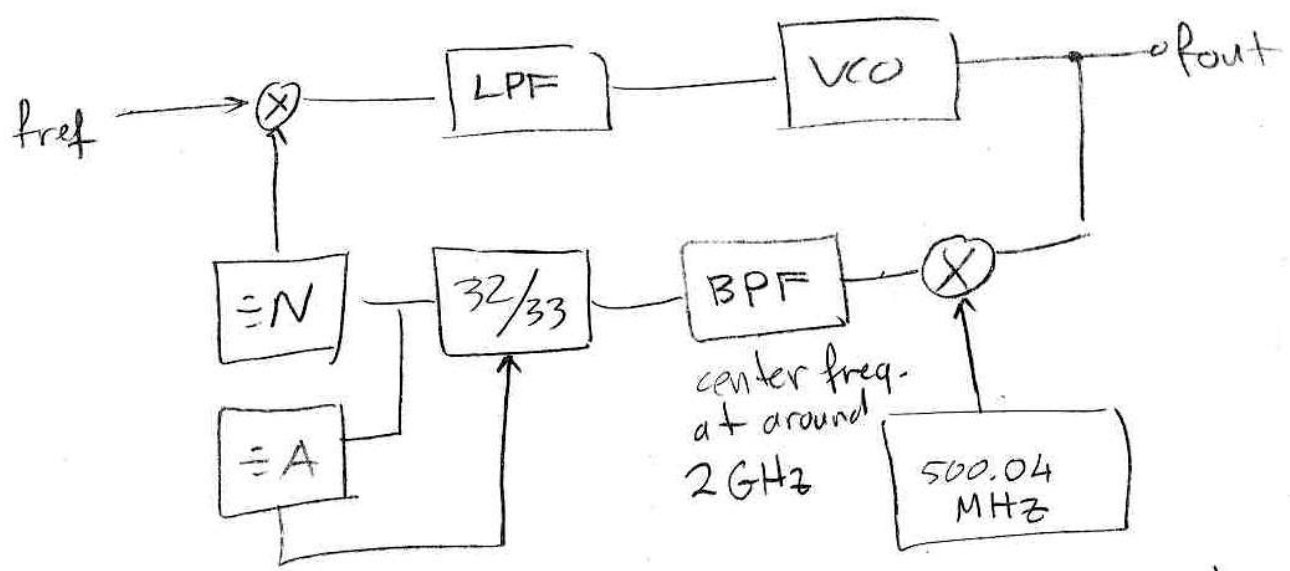
$$N = 767$$

$$A = 24550 - 32 \times 767 = 6$$

which satisfies the condition $A < N$

Q5/3

c-) For the new requirement we need an offset frequency which cannot be obtained as a multiple of the reference frequency, as a solution, we can introduce an offset which by making use of a mixer.



500 MHz was chosen so that the other sideband can easily be filtered out

d-) Assuming that the BPF is tuned to 2.45 - 0.5 GHz
 the input frequency to 32/33 divider is
 $2455.24 - 500.04 = 1955.2 \text{ MHz}$
 $\frac{1955.2}{0.1} = 19552$ is the division ratio

Q5/4

$$\frac{19522}{32} = 611.000 \Rightarrow$$

$$N = 611$$

$$19522 = N \times 32 + A$$

$$19522 - 611 \times 32 = A = 0.$$