**UNIVERSITY OF SASKATCHEWAN**
MIDTERM EXAMINATION

**EE 458.3 Communication Electronics**

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|---|---|---|
| Professor: | Dr. D. M. Klymyshyn | March 1, 2005 |
| Time: | **85 minutes** | |
| Notes: | Exam is **closed book.** 2 pages of formulas are allowed.<br>All 4 questions are of equal value. | |

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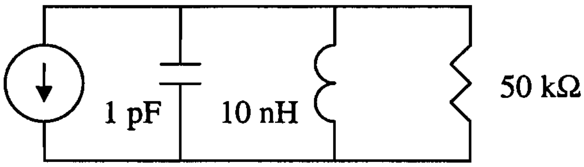
~~1.~~ What is the $Q$ of the following resonant circuit? Assume that the inductor alone has an unloaded $Q_{ind} = 46$ at 100 MHz.



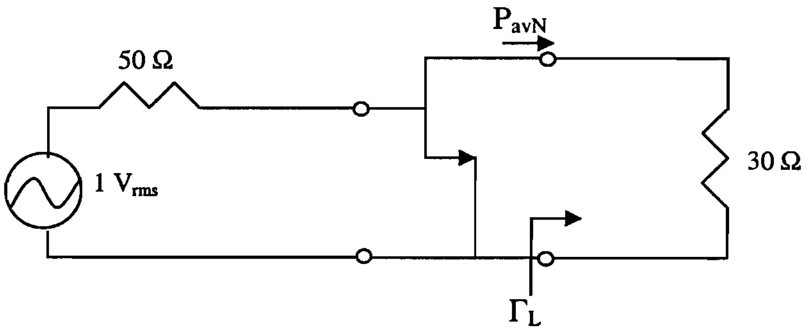

$Q_{ind} = \frac{\omega_0 L}{r_s}$

$r_s = 0.137$

$R_p = 289$

$Q = \frac{[illegible]}{\omega_0 L} =$ [illegible]

~~2.~~ For the following circuit in a 50 Ω system, calculate the transducer power gain. The power available from the network ($P_{avN}$) is 500 mW when $\Gamma_L = 0.5\angle 90°$.



3. The [S] parameters of a **potentially unstable** transistor measured in a 50 Ω system are given. Evaluate the **load stability** of the transistor; a Smith Chart is included for your solution. Is the termination $\Gamma_L = 0.9\angle -80°$ a good choice for load termination? Explain.

$$[S_{trans}] = \begin{bmatrix} 0.75\angle 160° & 0.1\angle 20° \\ 8.2\angle 50° & 0.25\angle 0° \end{bmatrix}$$

4. The [S] parameters for a transistor as measured in a 50Ω system are given. Find **real** valued source and load terminations to give a transducer power gain $G_T = 10$ dB. Use the attached Smith Chart for your solution. You do not need to design the matching circuits.

$$[S_{trans}] = \begin{bmatrix} 0.72\angle 20° & 0 \\ 2.51\angle 100° & 0 \end{bmatrix}$$

# UNIVERSITY OF SASKATCHEWAN
# EXAMINATION BOOKLET

*PLEASE PRINT CLEARLY*

SURNAME NESS

FIRSTNAME KYLE

STUDENT NUMBER 9 6 1 0 1 6

CLASS (e.g. BIOL 110 02) E E 4 5 8 0 2

SUBJECT COURSE NUMBER SECTION NUMBER

BOOKLET NUMBER 1

TOTAL NUMBER OF BOOKLETS HANDED IN 1

I declare that I am the person named. I am formally registered as a student in the class indicated on this cover page.

SIGNATURE Kyle Ness

DATE March 1, 2005

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| TOTAL | 30 |

Revised November 2000

(1)

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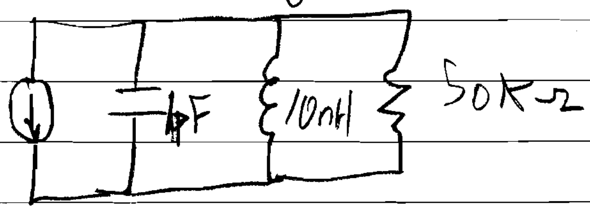
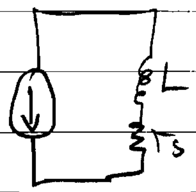
$Q_{ind} = 46$ at 100MHz

$$Q_{ind_{new}} = \frac{(10\times10^{9}\frac{rad}{s})(10\times10^{-9}H)}{0.137\Omega} = 729.93$$



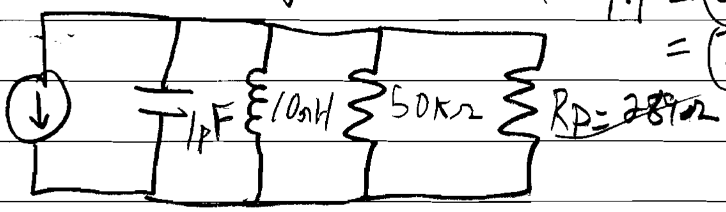

$$Q_{ind} = \frac{\omega_0 L}{r_s}$$

$$r_s = \frac{\omega_0 L}{Q_{ind}} = \frac{2\pi(100\times10^{6})(10\times10^{-9}H)}{46}$$

$$r_s = 0.137\,\Omega$$

$$\cancel{R_p = (Q_{ind})^2 r_s = (46)^2(0.137\Omega) = 289\Omega}$$

$\Downarrow$




$$R_p = (Q_{ind_{new}})^2 r_s = (729.93)^2(0.137\Omega) = 73K\Omega$$

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(1\times10^{-12}F)(10\times10^{-9}H)}} = 10\times10^{9}\frac{rad}{s}$$

$$\cancel{Q = \frac{R_p \parallel 50k\Omega}{\omega_0 L} = \frac{\frac{(289\Omega)(50\times10^3\Omega)}{289\Omega + 50\times10^3\Omega}}{(10\times10^{9}\frac{rad}{s})(10\times10^{-9})}}$$

$$\cancel{\boxed{Q = 2.87}}$$

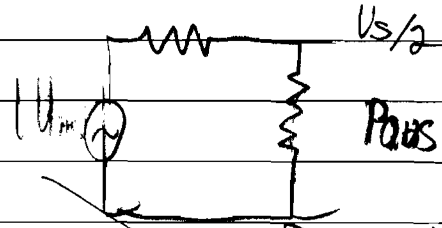
$$Q = \frac{R_p \parallel 50k\Omega}{\omega_0 L} = \frac{\frac{(73\times10^3\Omega)(50\times10^3\Omega)}{73\times10^3\Omega + 50\times10^3\Omega}}{(10\times10^{9}\frac{rad}{s})(10\times10^{-9})}$$

$$\boxed{Q = 297}$$

(2) $P_{AVN} = 500\,mW$ $\quad \Gamma_L = 0.5\angle 90°$

$Z_0 = 50\Omega$ ~~Man~~

Find $G_T$




$$P_{AVS} = \frac{|V_s|^2}{8Z_0} = \frac{(1V)^2}{8(50\Omega)} = 2.5\,mW$$

$$P_{AVS} = \frac{|V_s|^2}{4Z_0} = \frac{(1V_{rms})^2}{4(50\Omega)}$$

$P_{AVS} = 5\,mW$

$$\cancel{P_{AVS} = \frac{(V_{rms}/2)^2}{Z_0} = \frac{(0.5V)^2}{50\Omega} =}$$

No since $Z_L \neq Z_{OUT}$

~~Need $P_L$ since $G_T = \frac{P_L}{P_{AVS}}$~~

$$\cancel{P_L = P_{AVN}(1-|\Gamma_L|^2) = 500mW(1-|0.5|^2) = 375\,mW}$$

$$\cancel{\therefore G_T = \frac{375mW}{2.5mW} = \boxed{150\ (21.76\,dB)}}$$

~~Since we have some power reflected off the load b/c $\Gamma_L$ is not 0 meaning no reflection we get $P_L < P_{AVN}$ and can then find $G_T$.~~

$\Gamma_{OUT} = 0.5\angle -90° = -j0.5$

$P_L = P_{AVN} M_L$

$$M_L = \frac{(1-|\Gamma_L|^2)(1-|\Gamma_{OUT}|^2)}{|1-\Gamma_L\Gamma_{OUT}|^2} = \cancel{1-0.08}\ 0.692$$

$$G_T = \frac{P_L}{P_{AVS}} = \frac{P_{AVN}M_L}{P_{AVS}} = 69.2\ (18.4\,dB)$$

③ Evaluate stability 10

$\Delta = S_{11}S_{22} - S_{12}S_{21}$

$\Delta = (0.75\angle 160°)(0.25\angle 0°) - (0.1\angle 20°)(8.2\angle 50°)$

$\Delta = 0.841\angle -123°$

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{21}S_{12}|}$$

$$K = \frac{1 - (0.75)^2 - (0.25)^2 + (0.841)^2}{2|(0.1\angle 20°)(8.2\angle 50°)|}$$

$K = 0.66$

Since $K < 1$ & $\Delta > 1$ we have potentially unstable system as stated in question.

$$C_L = \frac{(S_{22} - \Delta S_{11}^*)^*}{|S_{22}|^2 - |\Delta|^2} = \frac{0.25\angle 0° - [(0.841\angle -123°)(0.75\angle -160°)]^*}{(0.25)^2 - (0.841)^2}$$

$C_L = 0.968\angle -100°$

$$r_L = \left|\frac{S_{12}S_{21}}{|S_{22}|^2 - |\Delta|^2}\right| = \left|\frac{(0.1\angle 20°)(8.2\angle 50°)}{(0.25)^2 - (0.841)^2}\right|$$

$r_L = 1.27$

Since $|S_{11}| < 1$ then $\Gamma_L = 0$ corresponds to the center of the smith chart and $|\Gamma_{in}| = |S_{11}|$ So.

Yes $\Gamma_L = 0.9\angle -80°$ is a good choice because when $\Gamma_L = 0$ $|\Gamma_{in}| = |S_{11}|$ and and so $|\Gamma_{in}| < 1$ inside the circle drawn on the smith chart and so load is stable here and when $\Gamma_L = 0.9\angle -80°$ it falls inside this circle.

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(4) $\Delta = S_{11}S_{22} - S_{12}S_{21}$

$\Delta = (0.72\angle 20^\circ)(0) - (0)(2.51\angle 100^\circ)$

$\Delta = 0\angle 0^\circ$

Unilateral Case

$G_o = |S_{21}|^2 = (2.51)^2 = 6.3 \quad (7.99\,dB)$

$G_{S\,max} = \dfrac{1}{1-|S_{11}|^2} = \dfrac{1}{1-(0.72)^2} = 2.076 \quad (3.17\,dB)$

$G_{L\,max} = \dfrac{1}{1-|S_{22}|^2} = 1 \quad (0\,dB)$

No gain can be retrieved from the load but you can get some from the source.

To get $G_T = 10$ we need $G_S = 10 - 7.99 = 2\,dB$ ✓

√ $g_{2dB} = \dfrac{2\,dB}{3.17\,dB}$ linear $= 0.631$ .626

$C_{gi} = \dfrac{g_{2dB}\,S_{11}^*}{1-|S_{11}|^2(1-g_{2dB})} = \dfrac{0.631(0.72\angle -20^\circ)}{1-(0.72)^2(1-0.631)}$

$C_{gi} = 0.567\angle -20^\circ$

$\Gamma_{g2dB} = \dfrac{\sqrt{1-g_{2dB}}\,(1-|S_{11}|^2)}{1-|S_{11}|^2(1-g_{2dB})}$

$= \dfrac{\sqrt{1-0.631}\,(1-(0.72)^2)}{1-(0.72)^2(1-0.631)}$

$\Gamma_{g2dB} = 0.362$ .267

resistive load termination of either:

$(12)(50) = \boxed{600\,\Omega}$ OR $(1.59)(50\,\Omega) = \boxed{79.5\,\Omega}$

will yield $G_T = 10\,dB$.

For the load

$g_i = 0dB$

$C_{0dB} = 0$

$\Gamma_{gi} = \frac{\sqrt{1-0}\,(1-|S_{22}|^2)}{1-|S_{22}|^2(1-0)} = \frac{1\,(1-0)}{1-0} = \underline{\underline{1}}$

Any where on the edge of the smith chart will make the load gain = 0dB so for real values either a short or an open at the load termination will yield a gain of 0dB using a purely real load termination.

50Ω

$g_{0dB} = \frac{10^{\left(\frac{2dB}{10}\right)}}{10^{\left(\frac{3.17dB}{10}\right)}} = \frac{1.58}{2.07} = \underline{0.7638}$

$C_{gi} = \frac{0.7638\,(0.72\angle -20°)}{1-(0.72)^2(1-0.7638)} = \underline{0.626\angle -20°}$

$\Gamma_g = \frac{\sqrt{1-0}\;\sqrt{1-0.7638}\;\left(1-(0.72)^2\right)}{1-(0.72)^2(1-0.7638)} = 0.261$

Source termination of

$Z_S = 125\Omega$ or $35\Omega$

$Z_L = 50\Omega$