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HW Assignment #4

1)

a) $S_I = -80\,dBm$

$SNR_{I_{dB}} = S_{I_{dB}} - N_{i_{dB}} \Rightarrow N_{i_{dB}} = S_{I_{dB}} - SNR_{I_{dB}} \Rightarrow N_{i_{dB}} = -80\,dBm - 35\,dB$

$\boxed{\Rightarrow N_{i_{dB}} = -115\,dBm}$

$\frac{SNR_I}{SNR_o} = 1 + \frac{kT_oB}{N_i}(F-1)$

$N_i = 10^{-11.5}\,mW$

$SNR_i = 10^{3.5}$

$\boxed{\Rightarrow N_i = 3.16\times10^{-15}\,W}$

$\Rightarrow SNR_o = \frac{SNR_I}{1 + \frac{kT_oB}{N_i}(F-1)} \Rightarrow F = 10^{0.5}$

$SNR_o\Big|_{N_i=-80dB} = 111.4 = \boxed{20.46\,dB}$

b) $S_I = -70\,dBm \Rightarrow N_{i_{dB}} = -105\,dBm \Rightarrow \boxed{N_i = 3.16\times10^{-14}\,W}$

$SNR_o = 845.88 = \boxed{29.27\,dB}$

c) $S_I = -60\,dBm \quad N_{i_{dB}} = -95\,dBm \Rightarrow N_i = \boxed{3.16\times10^{-13}\,W}$

$SNR_o = 2482.47 = \boxed{33.94\,dB}$

d) $F = \frac{SNR_i}{SNR_o}$ if and only if N_i is at $T = 290°K$

$\underbrace{F_{dB}}_{5dB} = \underbrace{SNR_{i_{dB}}}_{?} - \underbrace{SNR_{o_{dB}}}_{35dB} \Rightarrow SNR_{i_{dB}} = 40\,dB$

$SNR_i = \frac{S_i}{N_i} = \frac{S_i}{kT_oB} = 10^4$

$\Rightarrow S_i = 4.002\times10^{-10} = \boxed{-93.97\,dBm}$

2) $F = F_{min} + 4 \cdot r_n \dfrac{|\Gamma_s - \Gamma_{opt}|^2}{(1-|\Gamma_s|^2)\,|1+\Gamma_{opt}|^2}$

a)

$R_n = 10\Omega \Rightarrow r_n = \frac{10}{50} = 0.2$

$F_{min} = 10^{0.13} = 1.348$

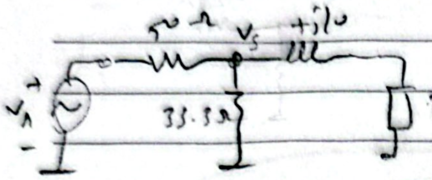
$\Gamma_s = \frac{50-50}{50+50} = 0$

Plug in the values:

$F = 1.748 = 2.427\,dB$

b) New source res $= \overset{50 // 33.3}{20} + j10$

$\hookrightarrow \Gamma_s = -0.4 + j0.2$



$V_s = V_1\left(\frac{33.3}{33.3+50}\right) = 0.4 V_1$

$P_{avs} = \left(\frac{V_1}{\sqrt{2}}\right)^2 \cdot \frac{1}{50} = \frac{V_1^2}{2\times 50}$

$P_{ava} = \left(\frac{V_s}{\sqrt{2}}\right)^2 \cdot \frac{1}{20} = \frac{V_s^2}{2\times 20}$

$G = \frac{P_{ava}}{P_{avs}} = \dfrac{\frac{(0.4V_1)^2}{2\times 20}}{\frac{V_1^2}{2\times 50}} = 0.4$

$\frac{T_{eq}}{R_{eq}} = \frac{T_{50}}{R_{50}} + \frac{T_{added}}{R_{added}} \Rightarrow \frac{290}{50} + \frac{300}{33.3} = \frac{T_{eq}}{20}$

$\hookrightarrow T_{eq} = 296.2\,°K$

$F_1 = \frac{T_{eq}}{T_0 \cdot G} = \frac{296.2}{290 \cdot 0.4} = 2.55 = 4.07\,dB$

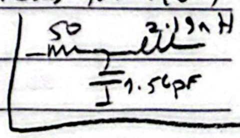
Because we used perfect matching, $F_2 = F_{min} = 1.3\,dB$

$F = F_1 + \frac{F_2 - 1}{G} \Rightarrow F = 2.55 + \frac{10^{0.13}-1}{0.4} = 3.42 = \boxed{5.34\,dB}$

c) $\Gamma_{s_{opt}} = -0.4 + j0.2 = \frac{Z_s - Z_0}{Z_s + Z_0} \Rightarrow Z_s = Z_0 \frac{1+\Gamma_{sopt}}{1-\Gamma_{sopt}} = \boxed{20 + j10}$

$Y = G + jB \Rightarrow G = \frac{1}{50} = 0.02$

Final value: $\frac{1}{G + jB_c} + jX_L = 20 + j10$ (shunt capacitor + series inductor)



$\Rightarrow \frac{1}{0.02 + jB_c} + jX_L = 20 + j10 \rightarrow \frac{0.02 - jB_c}{(0.02)^2 + (B_c)^2} + jX_L = 20 + j10$

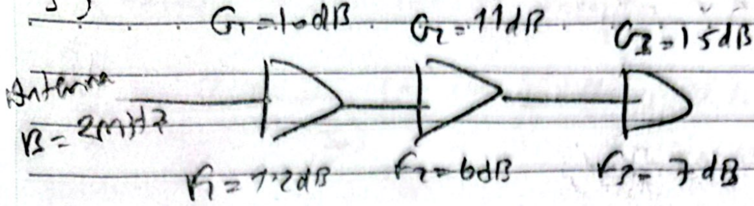
real part: $\frac{0.02}{(0.02)^2 + (B_c)^2} = 20 \Rightarrow B_c = 0.02449$

$jB_c = j\omega C \Rightarrow C = \frac{B_c}{\omega} = \boxed{1.56\,pF}$

$X_L - \frac{B_c}{(0.02)^2 + (B_c)^2} = 10$

$X_L = 34.49 = \omega L \Rightarrow L = \boxed{2.19\,nH}$

3)



a) $F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2}$

$F = 10^{0.12} + \frac{10^{0.6} - 1}{10^{1}} + \frac{10^{0.7} - 1}{10^{1} \cdot 10^{1.1}} = \boxed{1.648 = 2.17 dB}$

b) $N_0 = G_A k (T_{ant} + T_e) B$

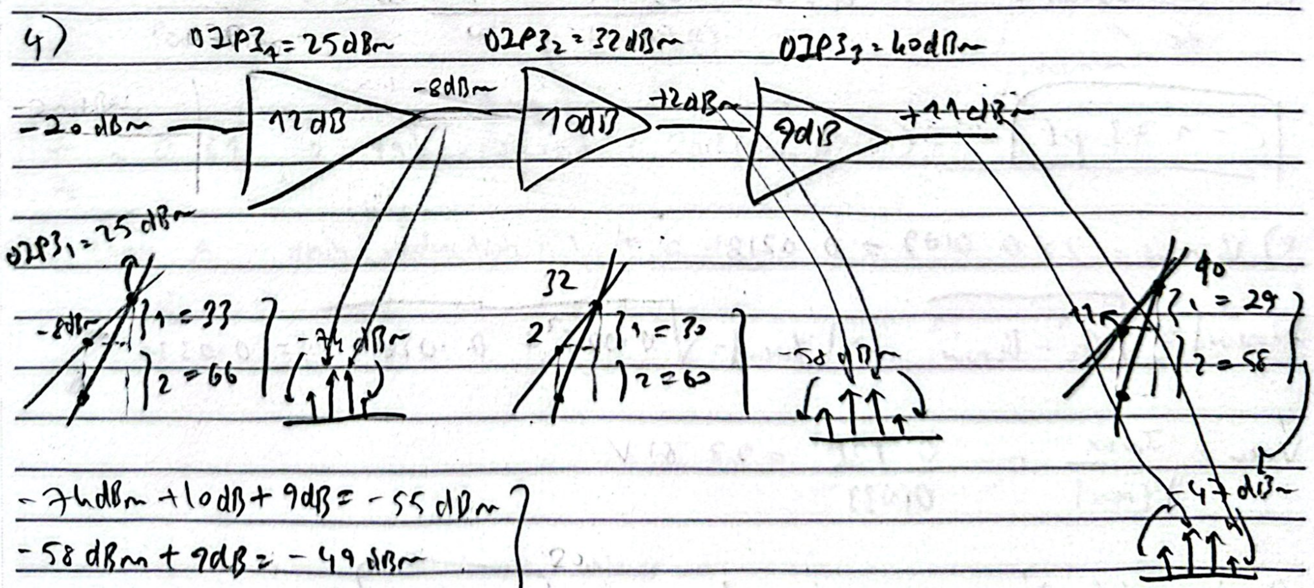
$T_e = T_{e1} + \frac{T_{e2}}{G_1} + \frac{T_{e3}}{G_1 G_2} = (F - 1) T_0 = \boxed{187.9^\circ K}$

$G_{A_{dB}} = G_{1_{dB}} + G_{2_{dB}} + G_{3dB} = 10 + 11 + 15 = 36 dB$

$N_0 = -73 dBm = 5.012 \times 10^{-11} W$

$\boxed{T_{ant} = \frac{N_0}{G_A k B} - T_e = 268.23^\circ K}$

4)



-74dBm + 10dB + 9dB = -55 dBm
-58 dBm + 9dB = -49 dBm
-47dBm

$20\log_{10}\left(10^{-55/20} + 10^{-49/20} + 10^{-47/20}\right) = \boxed{-40.18 dB}$

5) $V_{CC} - V_{SAT} = 28 - 0.5 = 27.5V = V_{peak}$

a) $I_Q = \frac{1.5A}{2} = 0.75A = I_{DC}$

$R_{Lopt} = \frac{V_{peak}}{I_{DC}} = \frac{27.5}{0.75} = 36.67\,\Omega$

b) $P_{opt} = \left[\frac{1}{\sqrt{2}}\left(\frac{I_{max}}{2}\right)\right]^2 R_{Lopt} = \frac{1}{2}(0.75)^2 \cdot 36.67 = \boxed{10.31W}$

c) $R_{Lopt} = 36.67\,\Omega$ $\quad R_L = 40\,\Omega$

$R_L > R_{Lopt} \Rightarrow$ voltage is limited

New current: $\frac{27.5}{40} = 0.6875A$

$P_{out} = \frac{V^2_{peak}}{2R_L} = \left[\frac{1}{\sqrt{2}}\left(\frac{I_{max}}{2}\right)\right]^2 \cdot R_L = \frac{1}{2} \cdot 0.6875^2 \times 40 = \boxed{9.45W}$

d) $G_{opt} = \frac{1}{R_{Lopt}} = \frac{1}{36.67} = 0.027$

$G_L = \frac{1}{R_L} = \frac{1}{40} = 0.025$

$Y_L = G_L + jB_L$

$B_L^2 = G_{opt}^2 - G_L^2$

$\hookrightarrow B_L \cong 0.0109$

$B_L = \frac{1}{\frac{1}{X_C}} \Rightarrow B_L = X_C \Rightarrow B_L = wC \Rightarrow C = \frac{B_L}{w} \Rightarrow C = \frac{0.0109}{2 \cdot \pi \cdot 10^9}$

$\boxed{C = 1.73\ pF}$

e) $B_{Lnew} = 2 \times 0.0109 = 0.0218$

$|Y_{new}| = \sqrt{G_L^2 + B_{Lnew}^2} \Rightarrow |Y_{new}| = \sqrt{0.025^2 + 0.026^2} = 0.033$

$V_{new} = \frac{I_{max}}{|Y_{new}|} = \frac{0.75A}{0.033} = 22.61V$

$P_{out} = \left(\frac{V_{new}}{\sqrt{2}}\right)^2 \cdot \frac{1}{R_L} = \frac{22.61^2}{2} \cdot \frac{1}{40} = \boxed{6.4W}$

b) a) $\alpha = 200° \rightarrow \frac{\alpha}{2} = 100° = 100 \times \frac{\pi}{180} = 1.745$ radians

$$I_1 = \frac{I_{max}}{2\pi(1-\cos\frac{\alpha}{2})}(\alpha - \sin\alpha) \overset{\sim}{=} 0.52\,A \quad (I_{max} = 1A)$$

(I_1: fundamental component)

$V_{DD} = 28 - V_{SAT} = 28 - 0.5 = 27.5V$

$$R_{opt} = \frac{V_{DD}}{I_1} = \frac{27.5}{0.52} = \boxed{52.9\,\Omega}$$

b) $P_{out} = \left(\frac{V_{DD}}{\sqrt{2}}\right)^2 \cdot \frac{1}{R_{opt}} = 7.15W$

$$P_{DC} = V_{DD} \cdot I_0 \Rightarrow I_0 = \frac{I_{max}}{2\pi} \frac{2\sin\frac{\alpha}{2} - \alpha\cos\frac{\alpha}{2}}{1-\cos\frac{\alpha}{2}} = 0.35A$$

$P_{DC} = 27.5 \times 0.35 = 9.6\,W$

$$\boxed{\eta = \frac{P_{out}}{P_{DC}} = 74.47\%}$$

c) Normalized power Gain $= \frac{I_1}{I_p} = \dfrac{\frac{I_{max}}{2\pi(1-\cos\frac{\alpha}{2})}(\alpha - \sin\alpha)}{\frac{I_{max}}{(1-\cos\frac{\alpha}{2})}} = \frac{\alpha - \sin\alpha}{2\pi}$

$\frac{I_1}{I_p} = 0.61 \rightarrow$ gain reduction $= 20\log_{10}(0.61) = \underline{-4.29\,dB}$ reduction

in Class A, gain reduction $= 1 = \underline{0\,dB}$