ASSIGNMENT 7

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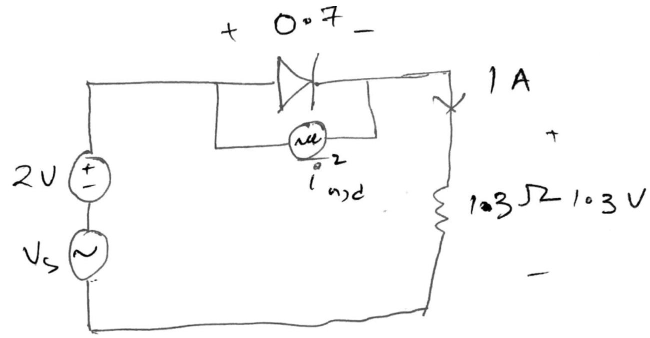
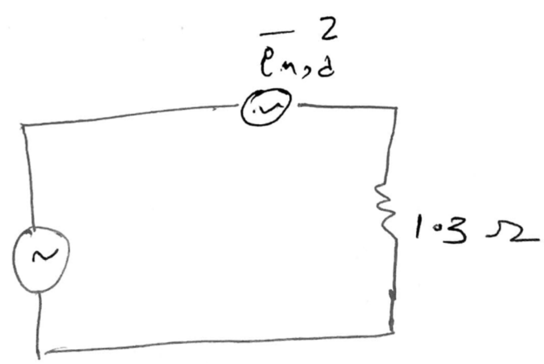
Problem 1

(a)



$$I_D = 1A$$
$$V_o = 1.3 + V_s$$

(b)



$$NoisePSD = 1.69 * 2 * 1.6 * 10^{-19} * 1$$
$$\implies \boxed{NoisePSD = 5.41e-19W/Hz}$$

(c)

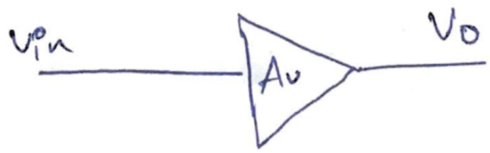
Here the gain is 1, any addition of resistance in series will reduce the gain. Thus there is **no resistance which can give the same gain**.

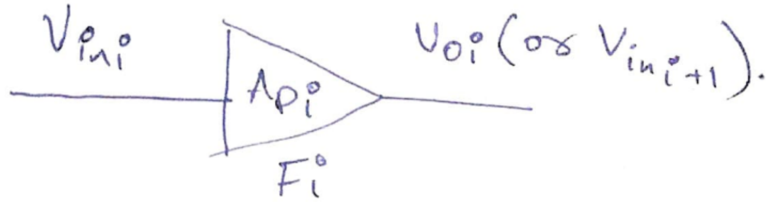
Problem 2

For the total chain,

$$F_{eff} = 1 + \frac{V_{n,in_3}^2}{(A_{p1}A_{p2}A_{p3})^2 V_{n,s}^2} + \frac{V_{n,in_2}^2}{(A_{p1}A_{p2})^2 V_{n,s}^2} + \frac{V_{n,in_1}^2}{(A_{p1})^2 V_{n,s}^2}$$

Take intermediate stage say ith stage,





$$F_i = \frac{A_{pi}^2 V_{n,in_i}^2 + V_{n,in_{i+1}}^2}{A_{pi}^2 V_{n,in_i}^2} = 1 + \frac{V_{n,in_{i+1}}^2}{A_{pi}^2 V_{n,in_i}^2}$$

And since, $A_{pi} = \frac{V_{in_{i+1}}}{V_{in_i}}$.

$$\boxed{F_{eff} = 1 + (1 - F_1)(1 - F_2)(1 - F_3) + (1 - F_1)(1 - F_2) + (1 - F_1)}$$

Problem 3

We find gain from input to output and just multiply the input noise PSD with square of magnitude of gain.

(a)

$$\frac{V_o}{V_{in}} = \frac{1}{sCR + 1}$$

$$NoisePSD = AvAv^* V_n^2 \implies \boxed{NoisePSD = \frac{1}{1 + (\omega CR)^2}}$$

(b)

$$\frac{V_o}{V_{in}} = \frac{1}{s^2LC + sCR + 1}$$

$$\implies \boxed{NoisePSD = \frac{V_n^2}{(1-\omega^2LC)^2 + (\omega CR)^2}}$$

(c)

$$\frac{V_{o1}}{V_{in}} = \frac{s^2LC_2 + 1}{s^3RLC_1C_2 + s^2LC_2 + sR(C_1+C_2) + 1}$$

$$\implies \boxed{NoisePSD_1 = V_n^2 \frac{(1-\omega^2LC_2)^2}{(1-\omega^2LC_2)^2 + (\omega^3RLC_1C_2 - \omega R(C_1+C_2))^2}}$$

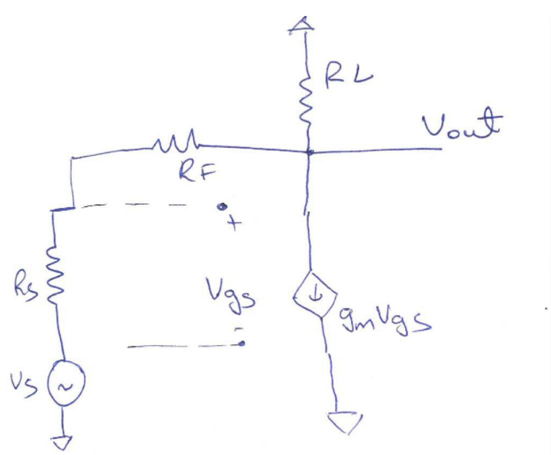
$$\frac{V_{o2}}{V_{in}} = \frac{1}{s^3RLC_1C_2 + s^2LC_2 + sR(C_1+C_2) + 1}$$

$$\implies \boxed{NoisePSD_2 = V_n^2 \frac{1}{(1-\omega^2LC_2)^2 + (\omega^3RLC_1C_2 - \omega R(C_1+C_2))^2}}$$

Problem 4

(a)

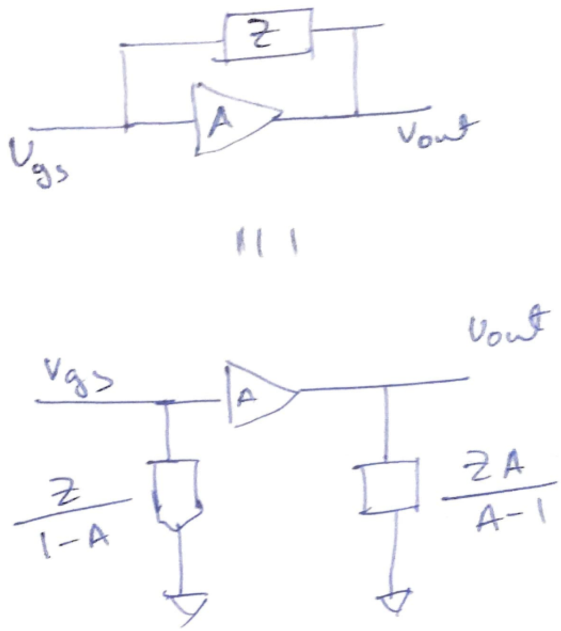
Small signal model



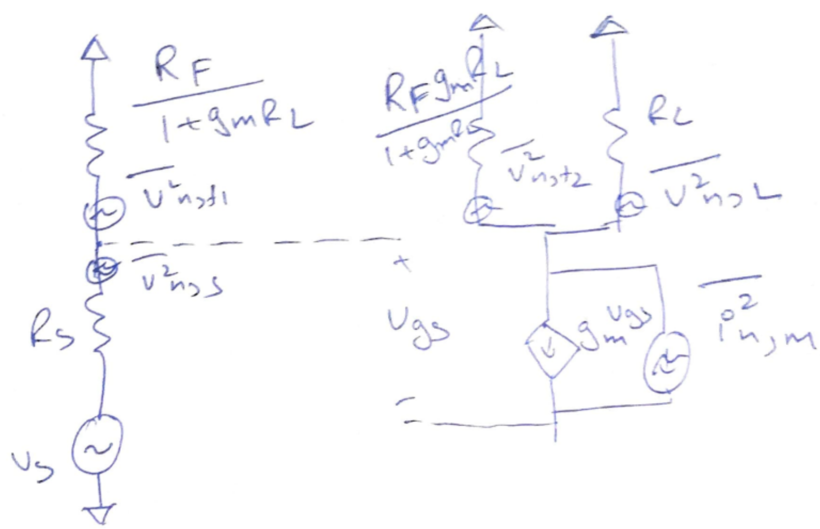
Effective gain here is $Av = \frac{V_{out}}{V_s} = -\frac{(g_m - 1/R_F)R_L}{1+\frac{1}{R_F}(R_L+R_s+g_mR_sR_L)}$.

Miller approximation

The following circuits are equivalent.



Applying miller approximation on our small signal circuit we get, here A is open loop gain which is $-g_m R_L$



$$I/PNoise = 4KT\left(R_s + \frac{R_F}{1+g_mR_L}\right)\left(g_m\left(R_L||\frac{g_mR_L}{1+g_mR_L}R_F\right)\right)^2$$

$$O/PNoise = I/PNoise + 4KTrg_m\left(R_L||\frac{g_mR_L}{1+g_mR_L}R_F\right)^2 + 4KT\left(\frac{g_mR_L}{1+g_mR_L}R_F\right)$$

$$NF = \frac{O/PNoise}{I/PNoise}$$

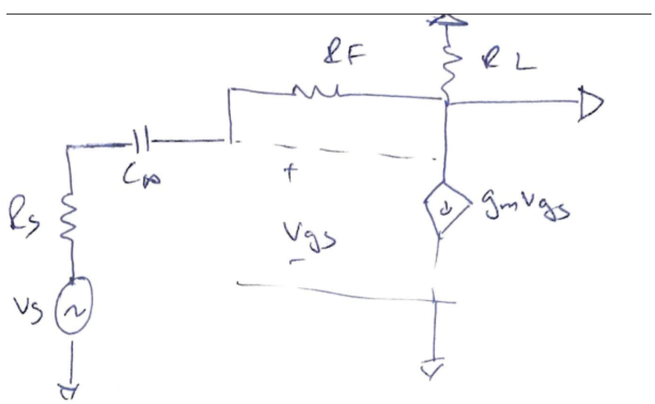
$$\implies NF = 1 + \frac{r}{g_m\left(R_s + \frac{R_F}{1+g_mR_L}\right)} + \frac{\left(\frac{g_mR_L}{1+g_mR_L}R_F\right)}{g_m^2\left(R_s + \frac{R_F}{1+g_mR_L}\right)\left(R_L||\frac{g_mR_L}{1+g_mR_L}R_F\right)^2}$$

$$R_F >> g_mR_LR_s$$

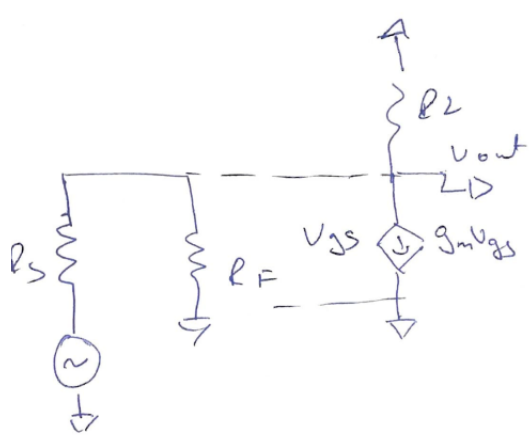
$$\implies \boxed{NF = 1 + \frac{rR_L}{R_F} + \frac{R_L}{g_mR_F}}$$

(b)

Small signal model



The gain here is zero. Thus using miller approximation. At output only noise would apprear.

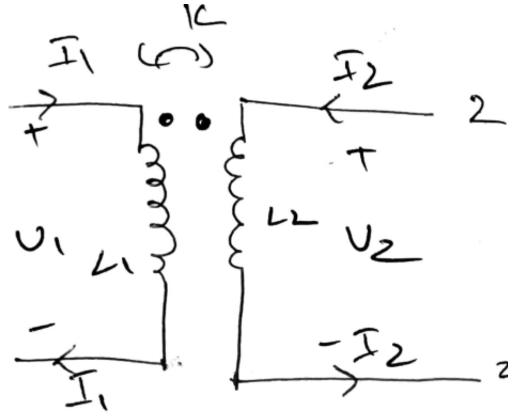


$$I/PNoise = 4KT(R_s + R_F)$$
$$O/PNoise = 4KT(R_s + R_F) + 4KTrg_mR_L^2$$
$$\implies \boxed{F = 1 + \frac{rg_mR_L^2}{R_s + R_F}}$$

Problem 5

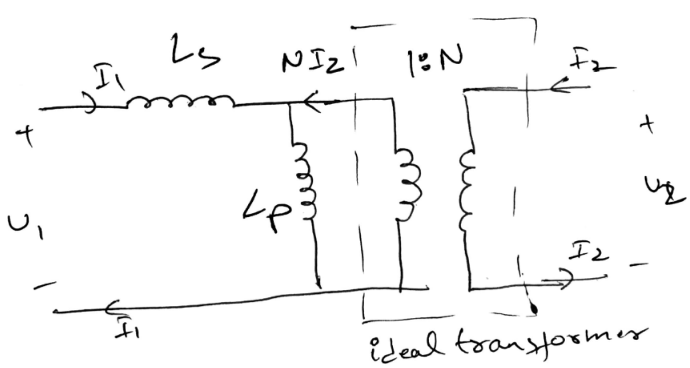
We can find Z-parameters for both the models and just equate corresponding parameters.

Model 1



$$V_1 = sL_1I_1 + sMI_2$$
$$V_2 = sMI_1 + sL_2I_2$$
$$M = K\sqrt{L_1L_2}$$

Model 2



$$V_1 = s(L_s + L_p)I_1 + sNL_pI_2$$
$$V_2 = sNL_pI_1 + sN^2L_pI_2$$

From above equations we conclude that,

$$L_1 = L_s + L_p$$
$$NL_p = K\sqrt{L_1 L_2}$$
$$N^2 L_p = L_2$$
$$\implies \boxed{N = \frac{1}{K}\sqrt{\frac{L_2}{L_1}}}$$
$$\implies \boxed{L_p = K^2 L_1} \implies \boxed{L_s = (1-K^2)L_1}$$

Problem 6

At receiver,

$$NF = SNR_{in} - SNR_{out} = 10dB$$
$$SNR_{in} = 10dB + SNR_{out} \geq 10dB$$
$$\implies P_{Rx} \geq P_{noise} + 10dB \implies P_{Tx} - P_{atten} \geq P_{noise} + 10dB$$
$$\implies P_{atten} \leq P_{Tx} - (P_{noise} + 10dB)$$

Assuming the circuits are matched, P_{noise} would be $-173.8 + 10log_{10}B$ which is -123.8bB. Therefore,

$$\boxed{P_{atten} \leq 143.8dB}$$

Maximum of 143.8dB of atmospheric attenuation is allowed.