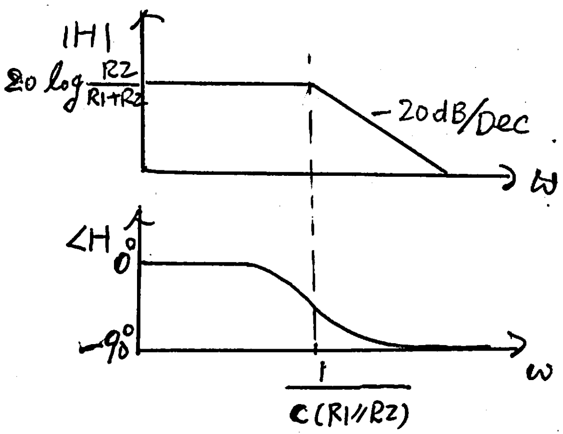
Q1 伝達関数 $H(s) = \dfrac{1}{CR1\,s + \left(\frac{R1}{R2}+1\right)}$

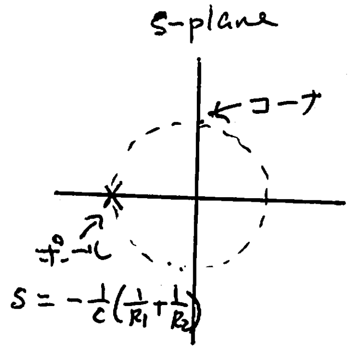
ポール $s = -\dfrac{1}{C}\left(\dfrac{1}{R1} + \dfrac{1}{R2}\right)$

周波数伝達関数 $H(j\omega) = \dfrac{1}{1 + j\omega C(R1/\!/R2)} \cdot \dfrac{R2}{R1+R2}$

コーナ周波数 $\omega_p = \dfrac{1}{C(R1/\!/R2)}$

ボーデ線図





Q2 伝達関数 $H(s) = \dfrac{LR2 \cdot s}{L(R1+R2)s + R1R2}$

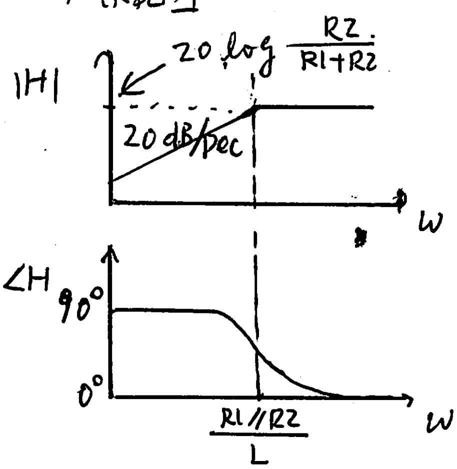
ゼロ $s = 0$

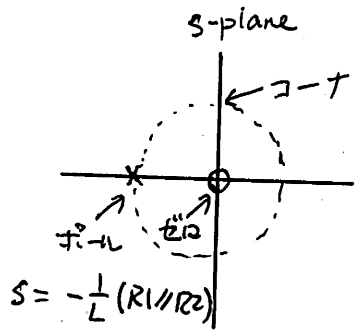
ポール $s = -\dfrac{1}{L}\dfrac{R1R2}{R1+R2}$

周波数伝達関数 $H(j\omega) = \dfrac{j\omega \frac{L}{R1}}{1 + j\omega \frac{L}{R1/\!/R2}}$

コーナ周波数 $\omega_p = \dfrac{R1/\!/R2}{L}$, $(\omega_z = 0)$

ボーデ線図





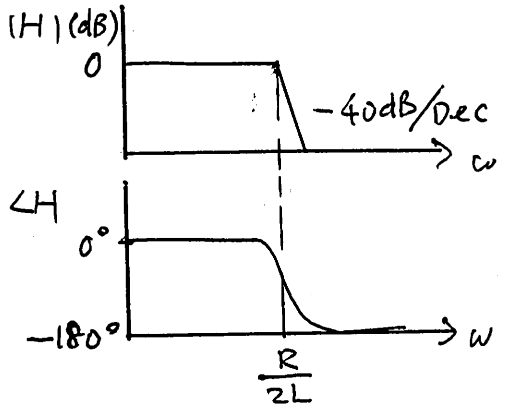
Q3

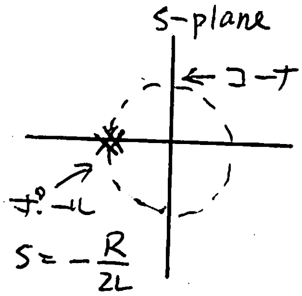
伝達関数 $H(s) = \dfrac{1}{\left(\frac{2L}{R}s+1\right)^2}$

ポール $s = -\dfrac{R}{2L}$ (2重)

周波数伝達関数 $H(j\omega) = \dfrac{1}{\left(1+j\omega\frac{2L}{R}\right)^2}$

コーナ周波数 $\omega_p = \dfrac{R}{2L}$



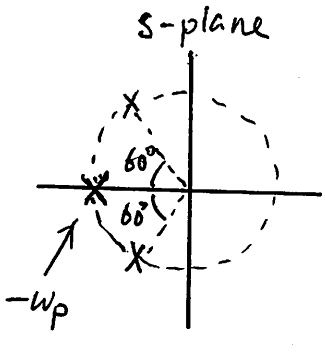


Q4

伝達関数 $H(s) = \dfrac{1}{\frac{L_1L_2C}{R}s^3 + L_1Cs^2 + \frac{L_1+L_2}{R}s + 1}$

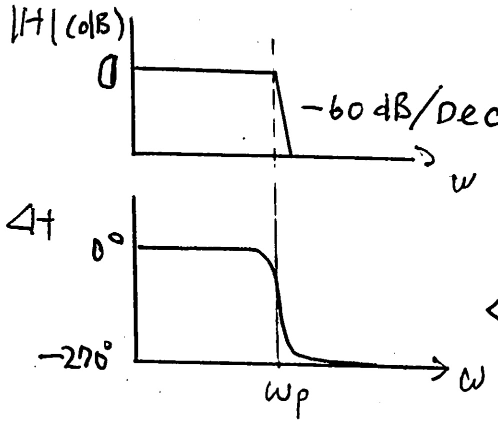
$\left(x = \frac{s}{\omega_p}\right.$ とおくと$\left.\right) = \dfrac{1}{(x+1)(x^2+x+1)}$

ポール $s = -\omega_p,\ \left(-\frac{1}{2} \pm j\frac{\sqrt{3}}{2}\right)\omega_p$



周波数伝達関数

$$H(j\omega) = \frac{1}{\left(1+j\frac{\omega}{\omega_p}\right)\left\{\left(1-\frac{\omega^2}{\omega_p^2}\right)+j\frac{\omega}{\omega_p}\right\}}$$



← $\omega \gg \omega_p$ のとき分母に $j\omega$ が残るため位相は負方向.

Q5 $$Z = \begin{bmatrix} R_1 + \dfrac{R_2}{1+j\omega C R_2} & \dfrac{R_2}{1+j\omega C R_2} \\ \dfrac{R_2}{1+j\omega C R_2} & \dfrac{R_2}{1+j\omega C R_2} \end{bmatrix}$$

$$Y = \begin{bmatrix} \dfrac{1}{R_1} & -\dfrac{1}{R_1} \\ -\dfrac{1}{R_1} & \dfrac{1}{R_1} + \dfrac{1}{R_2} + j\omega C \end{bmatrix}$$

$$F = \begin{bmatrix} 1 & R_1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \dfrac{1}{R_2} + j\omega C & 1 \end{bmatrix} = \begin{bmatrix} 1 + \dfrac{R_1}{R_2} + j\omega C R_1 & R_1 \\ \dfrac{1}{R_2} + j\omega C & 1 \end{bmatrix}$$

Q6 $$Z = \begin{bmatrix} R + j\omega L + \dfrac{1}{j\omega C} & \dfrac{1}{j\omega C} \\ \dfrac{1}{j\omega C} & \dfrac{1}{j\omega C} \end{bmatrix}$$

$$Y = \begin{bmatrix} \dfrac{1}{R+j\omega L} & -\dfrac{1}{R+j\omega L} \\ -\dfrac{1}{R+j\omega L} & \dfrac{1}{R+j\omega L} + j\omega C \end{bmatrix}$$

$$F = \begin{bmatrix} 1 & R+j\omega L \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ j\omega C & 1 \end{bmatrix} = \begin{bmatrix} 1 + j\omega C R - \omega^2 L C & R + j\omega L \\ j\omega C & 1 \end{bmatrix}$$

Q7 $$F = \begin{bmatrix} 1 & j\omega L_1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ j\omega C & 1 \end{bmatrix} \begin{bmatrix} 1 & j\omega L_2 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \dfrac{1}{R} & 1 \end{bmatrix}$$

$$= \begin{bmatrix} (1-\omega^2 L_1 C)(1 + j\omega \dfrac{L_2}{R}) + j\omega \dfrac{L_1}{R} & (1-\omega^2 L_1 C) j\omega L_2 + j\omega L_1 \\ j\omega C(1 + j\omega \dfrac{L_2}{R}) + \dfrac{1}{R} & 1 - \omega^2 L_2 C \end{bmatrix}$$

Q8 $$H(j\omega) = \frac{\overset{-y_{21}}{\cancel{-y_{21}(1+y_{11} r_s) - y_{11} y_{21} r_s}}}{(1 + y_{11} r_s)(y_{22} + \frac{1}{R_L}) - y_{12} y_{21} r_s}$$

Q9 $$H(j\omega) = -\frac{y_{21} - \frac{1}{R_F}}{y_{22} + \frac{1}{R_L} + \frac{1}{R_F}} \quad \left(Y = \begin{bmatrix} \frac{1}{R_F} & -\frac{1}{R_F} \\ -\frac{1}{R_F} & \frac{1}{R_F} \end{bmatrix} + \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \right)$$

Q10 $$H(j\omega) = \frac{1}{A + \frac{B}{R_L} + r_s\left(C + \frac{D}{R_L}\right)}$$

Q11

(1) M1 : $I_{D1} = 10.0\mu A$
M2 : $I_{D2} = -10.0\mu A$
M3 : $I_{D3} = 5.00\mu A$
M4 : $I_{D4} = -5.00\mu A$

(2) M1 : $V_{ov1} = \cancel{0.100}\ 0.141\,V$
M2 : $V_{ov2} = -\cancel{0.100}\ 0.141\,V$

(3) $V_{DS1} = \frac{VDD}{2} = 2.50V$

(4) $V_{DS1} = \frac{VDD}{2} = 2.50V$

(5) 動作点のドレーン電圧は下がる.

Q12

(1) M1 : $I_{D1} = 20.0\mu A$
M2 : $I_{D2} = -20.0\mu A$

(2) M1 : $V_{ov1} = 0.200V$
$V_{GS1} = V_{th} + V_{ov1} = 1.00V$

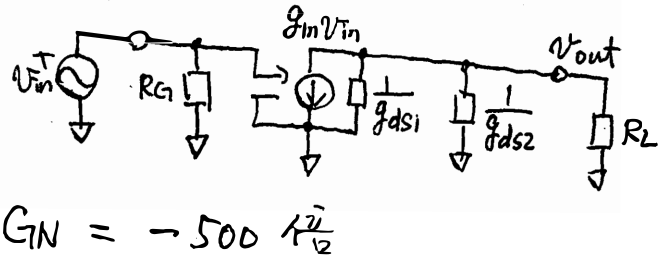
(3) $V_{DS1} = \frac{VDD}{2} = 2.50V$

(4) C1, C2 : 動作点を変えずに交流信号の入力と出力を行う.
(結合キャパシタ)

C3 : M3のG-S間の交流等価回路の電圧 $V_{GS3} = 0V$ としている
(バイパスキャパシタ)

(5) $g_{m1} = 0.200mS$, $g_{ds1} = 0.200\mu S$, $g_{ds2} = 0.200\mu S$

(6)



(7) $G_N = -500$ 倍

(8) $G_L = -1.99$ 倍

(9) 電圧利得は $\frac{1}{\sqrt{2}}$ 倍になる

(10)
$$Y = \begin{bmatrix} \frac{1}{R_G} & 0 \\ g_{m1} & g_{ds1}+g_{ds2} \end{bmatrix} = \begin{bmatrix} 1.00\mu S & 0.00\Omega \\ 0.200\mu S & 0.400\mu S \end{bmatrix}$$

Q13

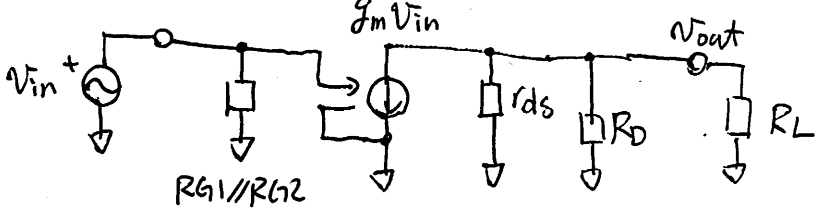
(1) $V_{ov} = V_{GS} - V_{Tn} = \dfrac{R_{G2}}{R_{G1}+R_{G2}} V_{DD} - V_{Tn}$

(2) $I_D = \dfrac{\beta_n}{2} V_{ov}^2 = \dfrac{\beta_n}{2}\left(\dfrac{R_{G2}}{R_{G1}+R_{G2}} V_{DD} - V_{Tn}\right)^2$

(3) $V_{DS} = V_{DD} - R_D I_D = V_{DD} - \dfrac{R_D \beta_n}{2} V_{ov}^2$

(4) $g_m = \dfrac{dI_D}{dV_{GS}} = \beta_n V_{ov} = \beta_n\left(\dfrac{R_{G2}}{R_{G1}+R_{G2}} V_{DD} - V_{Tn}\right)$

(5)



(6)

$$Y = \begin{bmatrix} \dfrac{1}{R_{G1}} + \dfrac{1}{R_{G2}} & 0 \\ g_m & \dfrac{1}{r_{ds}} + \dfrac{1}{R_D} \end{bmatrix}$$

(7) $G_H = -\dfrac{y_{21}}{y_{22}}$

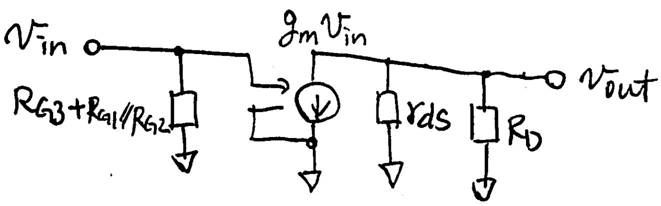
(8) $G_L = -\dfrac{y_{21}}{y_{22} + \frac{1}{R_L}}$

Q14

(1) $V_G = \dfrac{R_{G2}}{R_{G1}+R_{G2}} V_{DD}$, $V_D = V_{DD} - R_D \dfrac{\beta_n}{2} V_{ov}^2$, $V_S = R_S \dfrac{\beta_n}{2} V_{ov}^2$

(2) $n = \dfrac{1}{\dfrac{R_S \beta_n}{2V_{DD}} V_{ov}^2 + \dfrac{1}{V_{DD}} V_{ov} + \dfrac{V_{Tn}}{V_{DD}}} - 1$

(3)



(4) C1, C2 : 動作点（バイアス）を変えずに、交流信号を入出力する。
（結合キャパシタ）

C3 : RSに交流電圧が加わらないようにする。
（バイパスキャパシタ）

(5) RD : 電流信号を電圧信号に変換して出力する。

RS : 直流バイアス電流の変化を負帰還により抑制する。