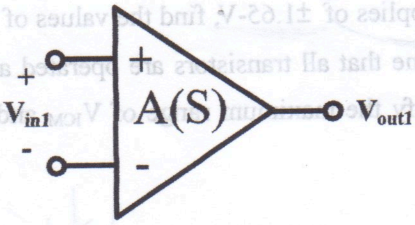
系級班別：＿＿＿＿＿＿ 學號：＿＿＿＿＿＿ 姓名：楊喬棣

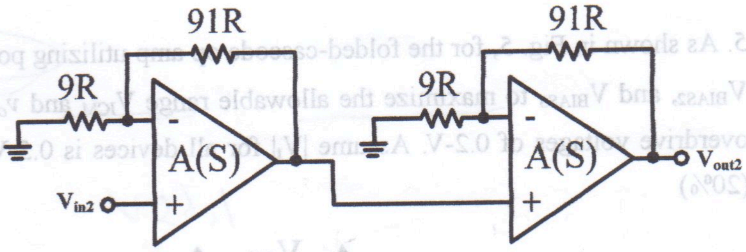
1. (a) With less than 25 words to list the name of the four feedback amplifiers (e.g. Trans… amplifier) and their corresponding topologies (e.g. series-shunt). (12%)
(b) Show how to derive A circuit and β circuit for a voltage amplifier. (8%)

2. A single-pole amplifier as shown in Fig.2(a) is designed to have a low-frequency gain of 100 and a pole at 10^6 Hz (i.e. $2\pi\times10^6$rad/sec). The single-pole amplifier (transfer function=A(S)) is used to design a feedback amplifier (transfer function=A_F(S) as shown in Fig.2(b).
(a) Derive A(S)) and draw its Bode plot. (4%) (b) What's the feedback type of the internal stage of the feedback amplifier? β for the internal stage=? (8%) (c) Derive A_F(S) and draw its Bode plot. (4%) (d)If the gain of the single-pole amplifier is decreased by 20%, what is the corresponding gain decrease in the feedback amplifier? (4%)



$$A(S)=\frac{V_{out1}(S)}{V_{in1}(S)}$$

Fig. 2(a)



$$A_F(S)=\frac{V_{out2}(S)}{V_{in2}(S)}$$

Fig. 2(b)

3. With less than 20 words, please give definitions for the following items of an operation amplifier.
(a) Slew Rate (7%)
(b) Unity-Gain-Band-Width (6%)
(c) Amplifier with rail-to-rail input operation (7%)

4. For a particular design of the two-stage CMOS op amp of Fig. 4. (Numerical answer is required.)
(a) ±1.65-V supplies are utilized and all transistors except for M6 and M7 are operated with overdrive voltages of 0.35-V magnitude; M6 and M7 use overdrive voltages of 0.45-V magnitude. The fabrication process employed provides $V_{tn}=|V_{tp}|=0.5$-V. Find the input common-mode range and the range allowed for v_o. (10%)
(b) With the process parameter $V'_{An}=|V'_{Ap}|=20V/\mu m$. Find A_1, A_2, and Av if all devices are 1μm long, $V_{ov1}=0.2$-V, and $V_{ov6}=0.5$-V. Also, find the op-amp output resistance obtained when the second stage is biased at 0.45mA. (A_1 and A_2 represent the A of the first and the second stage, respectively) (10%)

250V

$\frac{V_A' \cdot L}{I_D}$

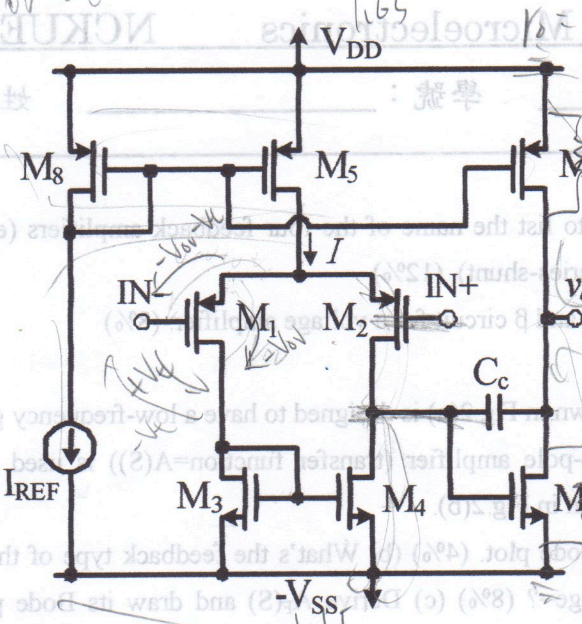


Fig. 4

$g_m = \frac{2I_D}{V_{OV}}$ $V_t = 0.5$

$g_m (r_{o2} \| r_{o4})$

5. As shown in Fig. 5, for the folded-cascode op amp utilizing power supplies of ±1.65-V, find the values of V_{BIAS1}, V_{BIAS2}, and V_{BIAS3} to maximize the allowable range V_{ICM} and v_o. Assume that all transistors are operated at equal overdrive voltages of 0.2-V. Assume $|V_t|$ for all devices is 0.5-V. Specify the maximum range of V_{ICM} and of v_o. (20%)

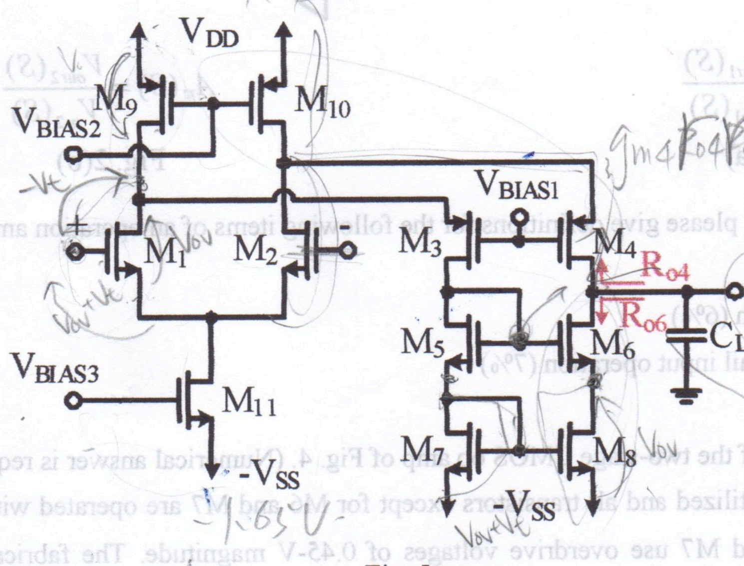


Fig. 5

$V_{ov} = V_{ds(sat)} = V_{GS} - V_t$

$V_{GS} = V_{ov} + V_t$

$-V_{SS} + V_{ov11} + V_{ov1} + V_t$

$-V_{SS} + V_{ov7} + V_t \le V_o \le V_{DD} - V_{ov10} - V_{ov4}$

系級班別：　　　　學號：　　　　姓名： 楊喬棟

(20%) 1. (a) With less than 25 words to list the name of the four feedback amplifiers (e.g. Trans… amplifier) and their corresponding topologies (e.g. series-shunt). (12%) (b) Show how to derive A circuit and β circuit for a voltage amplifier. Please give detailed procedure from two-port feedback network to A circuit and β circuit. (8%)

ok

(15%) 2. The noninverting op-amp configuration is shown in Fig. P2. (a) Assume that the OPAMP has infinite input resistance and zero output resistance. Find an expression for the feedback factor β. (5%) (b) If the open-loop voltage gain $A = 10^3$, find R_2/R_1 to obtain a close-loop voltage gain A_f of 10. (5%) (c) If A decreases by 30%, what is the corresponding decrease in A_f? (5%)

ok

(a) $\beta = \frac{R_1}{R_1+R_2}$

(b) $A_f = 10 = \frac{A}{1+\beta A} = \frac{10^3}{1+10^3\beta}$

$10+10^4\beta = 10^3$

$\beta = 0.099$

(c) $\frac{0.7\times10^3}{1+0.7\times10^3\times0.099} = 9.9573$

0.427%

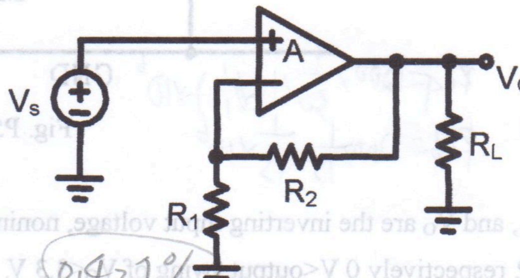


Fig. P2

(15%) 3. With illustrations, please give definitions for the following items of a two-pole OPAMP.

(a) -3dB bandwidth (5%)

(b) Unity-gain bandwidth (5%)

(c) Gain-bandwidth product (5%) $f_t = A_0 f_b$ -3dB bandwidth

The unity-gain bandwidth and bandwidth product of an op amp is the same with the frequency response is of the single-pole type.

(20%) 4. A cascode current mirror is shown in Fig. P4(a) and a wide-swing current mirror is shown in Fig. P4(b). The $|V_{OV}|$ for all transistors is 0.3 V and the $|V_t|$ is 0.7 V. All transistors are identical.

ok

(a) Please calculate V_{bias1} voltage, V_{bias2} voltage and the minimum voltage of V_O swing in Fig. P4(a). (10%)

(b) Please calculate V_{bias3} voltage, V_{bias4} voltage and the minimum voltage of V_O swing in Fig. P4(b). (10%)

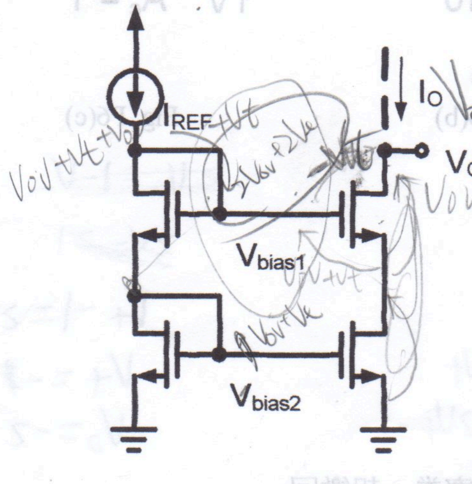


Fig. P4(a)

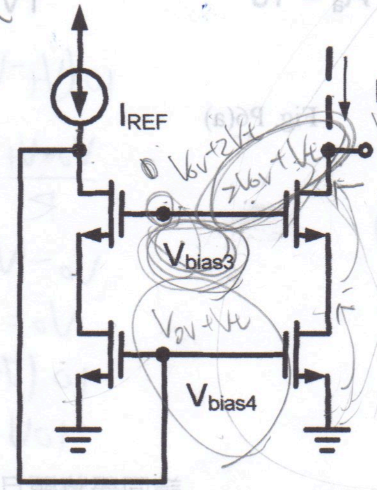


Fig. P4(b)

$I_D = \frac{\mu_n C_{ox}}{2}\frac{W}{L}(V_{GS}+V_{TN})^2(1+\lambda V_{DS})$.

$R_{o4} = g_{m4} r_{ds4} (r_{ds10} \| r_{ds2})$

$R_{o6} = g_{m6} r_{ds6} r_{ds8}$

(20%) 5. A folded-cascode OPAMP is shown in Fig. P5 where I_{M11} = 200 uA, I_{M10} = 250 uA, and $|V_{OV}|$ for all transistors is 0.25 V. Assume that the fabrication process $u_n C_{ox}$ = 200 uA/V^2, $u_p C_{ox}$ = 80 uA/V^2, λ_n = 0.1 um/V, λ_p = 0.2 um/V, V_{DD} = 3.3, V_{tn} = 0.7 V, and $|V_{tp}|$ = 0.8 V. Please find (a) The voltage gain and output resistance. (10%) (b) The input common-mode range and output voltage swing. (10%)

$A = g_m V_{out}$

$g_{m1} = \frac{2I}{V_{OV}} = \frac{2\times 100}{0.25} = 800\mu A/V$

$g_{m4} = \frac{2I}{V_{OV}} = \frac{2\times 150}{0.25} = 1200\mu A/V$

$g_{m6} = g_{m4}$

$r_{ds2} = \frac{1}{\lambda I_{DS}} = \frac{1}{0.1\times 100\mu A} = 0.1M\Omega$

$r_{ds4} = \frac{1}{0.2\times 150\mu A} = \frac{1}{30} M\Omega$

$r_{ds10} = \frac{1}{\lambda I_{DS}} = \frac{1}{0.2\times 250\mu A} = \frac{1}{50} M\Omega$

$r_{ds6} = r_{ds8} = \frac{1}{0.1\times 150\mu A} = \frac{1}{15} M\Omega$

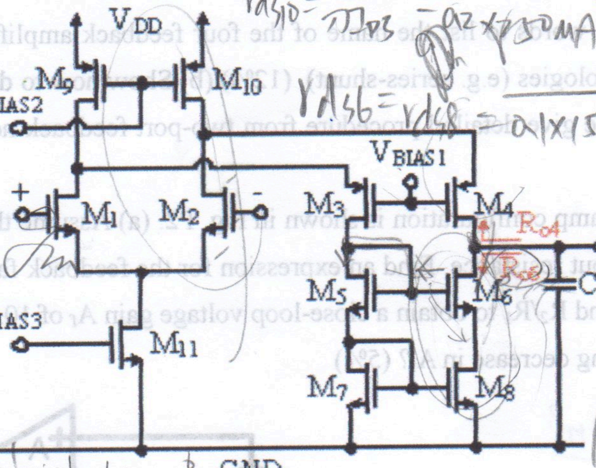


Fig. P5

$R_{o4} \| R_{o6} = 5.92 \times 10^3 \Omega$

$A = g_{m1} \times (R_{o4} \| R_{o6}) = 4.74074\ V/V$

$R_{o4} = 1200 \times \frac{1}{30} \times (\frac{1}{50} \| \frac{1}{10}) \times 10^6$

$R_{o6} = 1200 \times \frac{1}{15} \times \frac{1}{15} \times 10^6$

(15%) 6. V_-, V_+, and V_O are the inverting input voltage, noninverting input voltage, and output voltage of the OPAMP, respectively 0 V<output swing of V_O<3.3 V.

(a) Calculate V_- and V_O of the circuit shown in Fig. P6(a) where the OPAMP gain A_a = 10. (5%)

(b) Calculate V_+ and V_O of the circuit shown in Fig. P6(b) where the OPAMP gain A_b = 10. (5%)

(c) Calculate V_+ and V_O of the circuit shown in Fig. P6(c) where the OPAMP gain A_c = 1. (5%)

$V_o = A(V_+ - V_-)$

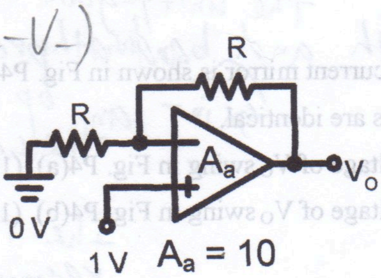


Fig. P6(a)

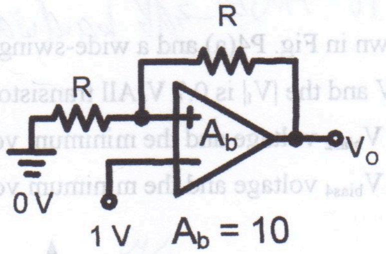


Fig. P6(b)

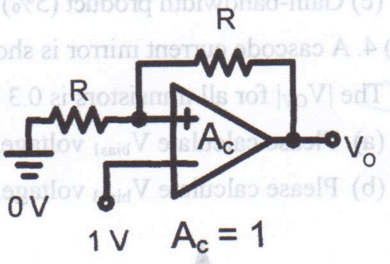


Fig. P6(c)

$\frac{V_o - V_-}{R} = \frac{V_-}{R}$

$V_o = 2V_-$

$2V_- = A(1 - V_-)$

$= 10 - 10V_-$

$12V_- = 10$

$V_- = \frac{10}{12} = \frac{5}{6}$

$V_o = \frac{5}{3}$

$10(V_+ - V_-) = V_o$

$\frac{V_o - V_+}{R} = \frac{V_+}{R}$

$V_o - V_+ = V_+$

$V_o = 2V_+$

$10(V_+ - 1) = 2V_+$

$10V_+ - 10 = 2V_+$

$8V_+ = 10$

$V_+ = \frac{10}{8} = \frac{5}{4}$

$V_o = \frac{5}{2}$

$\cancel{2V_- = 1 - V_-}$

$\cancel{3V_- = 1}$

$V_+ - 1 = 2V_+$

$V_+ = -1$

$V_o = -2$

請同學將題目卷隨同答案卷一起繳回

Midterm Exam I Microelectronics NCKUEE 10/27/2009

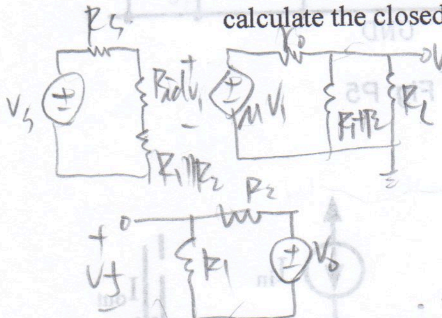
楊喬棟

(16%) 1. With less than 25 words, please list the name of the four feedback amplifiers (e.g. Trans… amplifier) and their corresponding topologies (e.g. series-shunt). (16%)

(15%) 2. Fig. P2 shows an op amp with a feedback network.

(a) Draw its A circuit and β circuit. (10%)

(b) If $\mu = 10^4$, $R_{id} = 50k\Omega$, $r_o = 2k\Omega$, $R_L = 5k\Omega$, $R_1 = 1k\Omega$, $R_2 = 1M\Omega$, and $R_s = 2k\Omega$, please calculate the closed-loop gain A_f. (5%)



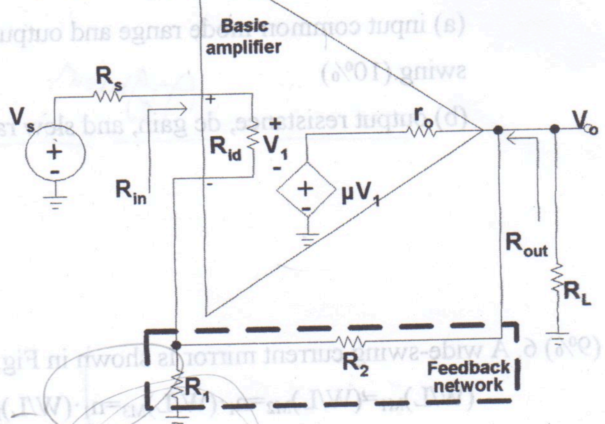


Fig. P2

$20\log|A\beta| = 20\log|A| - 20\log\frac{1}{\beta}$

(10%) 3. The open-loop gain Bode plot of an op amp is shown in Fig. P3. It's a three-pole system with pole locations on 10^4, 10^5, and 10^6 Hz. Assume that the β-circuit is independent of frequency.

(a) What is the acceptable range of β to prevent the system from unstable operation? (5%)

(b) What is the minimum closed-loop gain that can be obtained for phase margin of 45°? (5%)

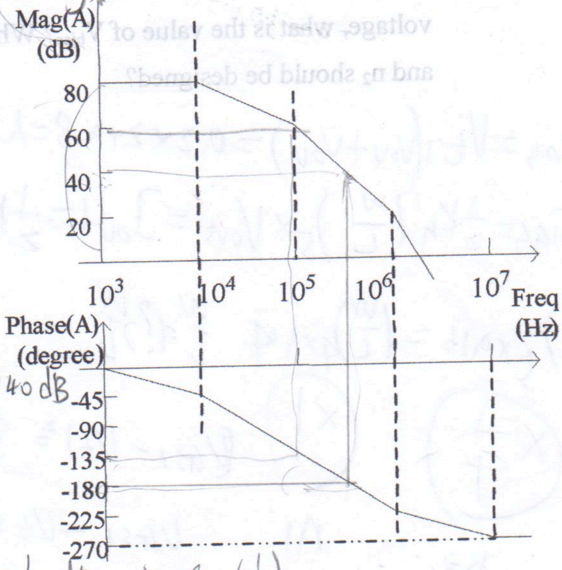


Fig. P3

$40 = 20\log\frac{1}{\beta} \Rightarrow \beta = 10^{-2}$

f_t 至少要劃到 $-180^\circ \Rightarrow 10^6 \Rightarrow 40$ dB

故平移 40 dB 以上

$20\log|\frac{1}{\beta}| = 40 \Rightarrow \beta = 10^{-2}$

$90^\circ - \tan^{-1}(\frac{f_t}{f_{p2}}) = 45^\circ$

$45^\circ = \tan^{-1}(\frac{f_t}{f_{p2}})$

$80 - 20\log(\frac{10^5}{10^4}) = 60\text{ dB} = 20\log(\frac{1}{\beta})$

P.884 $\tan\frac{f_t}{f_{p2}} = 1$ $f_t = f_{p2} = 10^5$

(25%) 4. Fig. P4 shows a two-stage CMOS op amp. Assuming $V_{OV1} = 0.2V$, $V_{OV6} = 0.5V$, and the process parameter $\lambda n = 0.05V^{-1}$ and $\lambda p = 0.1V^{-1}$.

(a) Find the output resistance R_{out}, first stage dc-gain A_1, a stage is biased at 500μA. (15%)

(b) How does the Cc influence the poles and/or zeros of the system? (5%)

(c) How does the Rc influence the poles and/or zeros of the system? (5%)

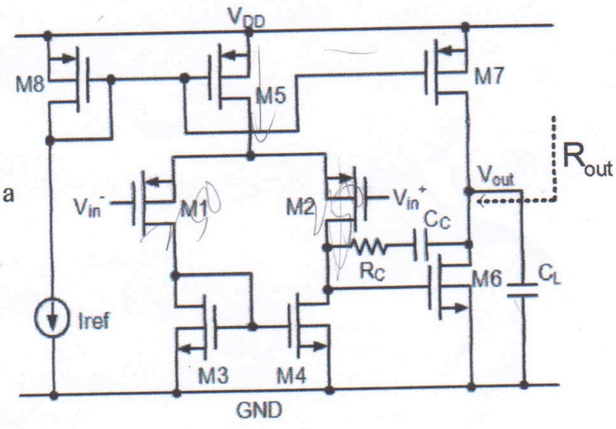


Fig. P4

$eA10^{-2}$

(25%) 5. A folded-cascode OPAMP is shown in Fig. P5 where

$I_{M11} = 200\mu A$, $I_{M10} = 300\mu A$, and $|V_{OV}|$ for all transistors is 0.2V. Assuming $\mu_n C_{ox} = 200\mu A/V^2$, $\mu_p C_{ox} = 80\mu A/V^2$, $\lambda n = 0.05V^{-1}$, $\lambda p = 0.1V^{-1}$, VDD = 3.3V, Vtn = 0.8 V, $|Vtp| = 0.8$ V, and C_L=5pF, please find

(a) input common-mode range and output voltage swing.(10%)

$A = g_m R_{out}$

(b) output resistance, dc gain, and slew rate.(15%)

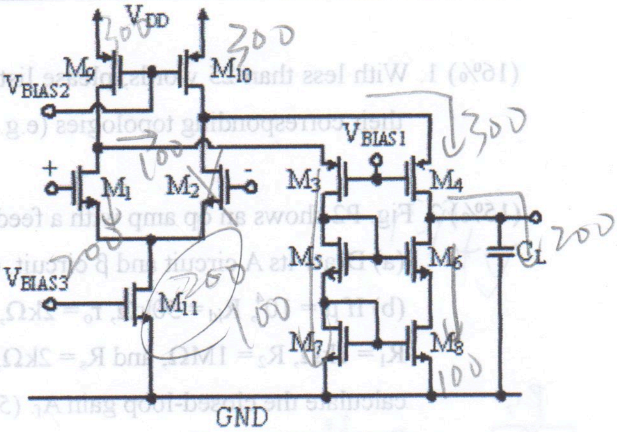


Fig. P5

(9%) 6. A wide-swing current mirror is shown in Fig. P6. Assume $(W/L)_{M1}=(W/L)_{M2}=n_1\cdot(W/L)_{M3}=n_1\cdot(W/L)_{M4}=n_2\cdot(W/L)_{M5}$, $I_{bias}=I_{in}=I_{out}$. The $|V_{OV}|$ for M_1,M_2,M_3,M_4 are 0.2V and the $|Vt|$ is 0.8V. In order to minimize the allowable output voltage, what is the value of V_{bias}? What are the values of n_1 and n_2 should be designed?

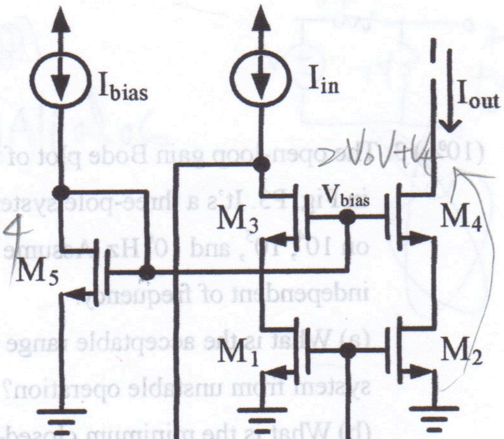


Fig. P6

$\therefore V_{ov5} = 0.4$

$V_{bias} = V_t + (V_{ov} + V_{ov}) = 0.2 \times 2 + 0.8 = 1.2 = V_{ov5} + 0.8$

$I_{bias} = \frac{1}{2} k_n' \left(\frac{W}{L}\right)_5 \times V_{ov5}^2 = I_{out} = \frac{1}{2} k_n' \left(\frac{W}{L}\right)_4 \times 0.2^2$

$\left(\frac{W}{L}\right)_5 \times 0.16 = \left(\frac{W}{L}\right)_4 \times 0.04 \quad \frac{W}{L} = (?)\frac{W}{L}$

$\times\frac{1}{4}$ $\times 1$

n_2 n_1

$(V_{GS1} - V_t)^2 = ?(V_{GS2} - V_t)^2$

$V_{GS1} - V_t = \sqrt{?}\cdot(V_{GS2} - V_t)$

$V_{GS1} = \sqrt{?}\, V_{GS2} - \sqrt{?}\, V_t + V_t$

$? = 4$

Mid-term Exam I Microelectronics (III) NCKUEE 10/26/2010

楊喬棟

(10%) 1. Feedback circuits can be classified into four basic topologies (e.g. Trans…amplifier). As shown in Fig. P1(a) and (b), please respectively specify which types the two configurations are. Explain your reasons.

(a) voltage amplifier

(b) transimpedance amplifier

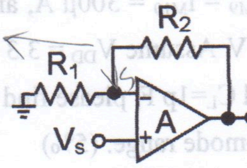


Fig. P1(a)

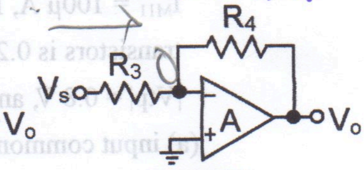


Fig. P1(b)

(20%) 2. The open-loop gain Bode plot of an op amp is shown in Fig. P2. It's a three-pole system with pole locations on 10^6 10^8 and 10^9 Hz. If the op amp is connected in the non-inverting configuration, as shown in Fig. P1(a).

(a) What is the acceptable range of (R_2/R_1) to prevent the system from unstable operation? (10%)

(b) If the phase margin of 63° is required, please find the unity-gain bandwidth of loop gain (Aβ), and the closed-loop gain.(10%)

(a) $\frac{R_2}{R_1} > 2.16$

(b) $90° - \tan^{-1}\left(\frac{f_t}{f_{p2}}\right) = 63°$

$f_t = 0.5 \times 10^8 = 5\times10^7$ Hz

$20\log\left(\frac{1}{\beta}\right) = 70 - 20\log\left(\frac{5\times10^7}{10^6}\right)$

$= 36.02$ dB

$\beta = 0.01458$

$\frac{A}{1+A\beta} = 64.5$ V/V

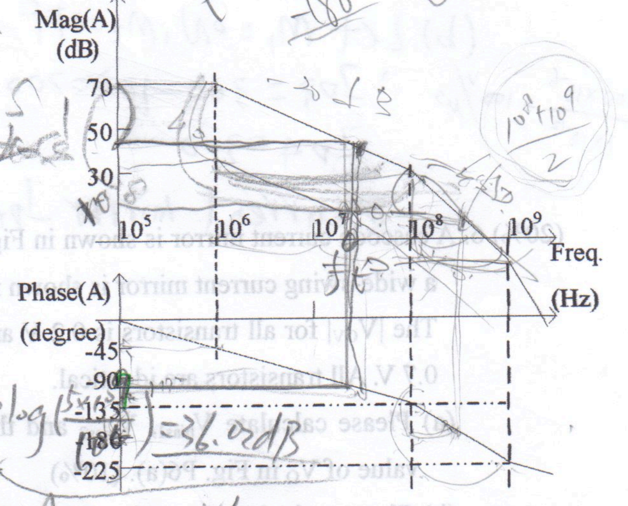


Fig. P2

$\frac{180-135}{225-135} = \frac{x-10^8}{10^9-10^8}$

$\frac{45}{90} = \frac{1}{2} = \frac{x-10^8}{10^9-10^8}$

$2x - 2\times10^8 = 10^9 - 10^8$

$2x = 10^9 + 10^8$

$x = \frac{10^8+10^9}{2}$

$20\log ? = 10$

$? = 2.16$

$\frac{1}{\beta} = 1 + \frac{R_2}{R_1}$

$\frac{R_2}{R_1} = 2.16$

(15%) 3. Consider a closed-loop circuit shown in Fig. P3. Assume input resistance of the basic amplifier is infinite, open-loop gain $\mu = 10^3$ V/V, $r_o = R_L = 100\text{k}\ \Omega$, $R_1 = R_2 = 50\text{k}\ \Omega$, $C_L = 1\text{p}$ F, please calculate the DC-gain of the loop gain, and the dominant pole location of the loop gain.

PL Gain $= \frac{1000}{6}$ V/V

$f_p = 4.77$ MHz

$27° = \tan^{-1}\left(\frac{f_t}{f_{p2}}\right)$

$0.5095 = \frac{f_t}{f_{p2}}$

$f_t = 0.5\times10^8 = 5\times10^7$ Hz

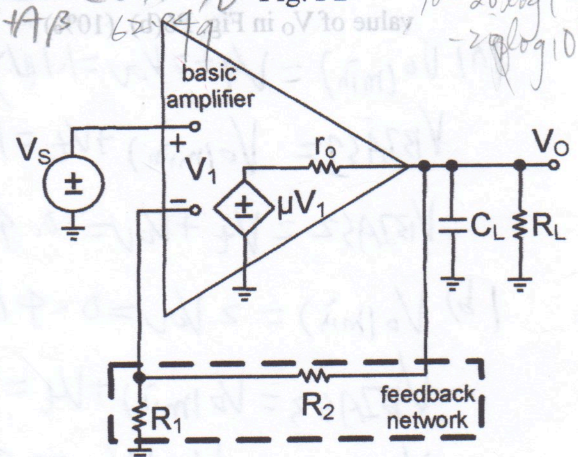


Fig. P3

(20%) 4. Fig. P4(a) shows the simplified small-signal circuit of a two-stage OP before frequency compensation. Let $G_{m1} = 1\text{m}$ A/V, $G_{m2} = 2\text{m}$ A/V, $R_1 = R_2 = 100\text{k}\ \Omega$, $C_1 = 0.5\text{p}$ F, $C_2 = 1\text{p}$ F.

$f_{p1} = \frac{1}{2\pi R_1 C_1}$, $f_{p2} = \frac{1}{2\pi R_2 C_2}$ 3.183 MHz, 1.591 MHz

(a) Calculate the pole locations of the system.

(b) C_A is added as shown in Fig. P4(b). To obtain a dominant pole located on 10k Hz, please find C_A.

(b) $C_A = 158.7$ pF

(c) C_C is inserted as shown in Fig. P4(c). To obtain a dominant pole located on 10k Hz, please find C_C.

(c) $f = \frac{1}{2\pi R_1 (C_1 + g_{m2} R_2 C_c)} \Rightarrow C_c = 0.8$ pF

(d) Please explain the benefit of inserting C_C.

Miller's Effect → large input capacitance

low 3-dB frequency

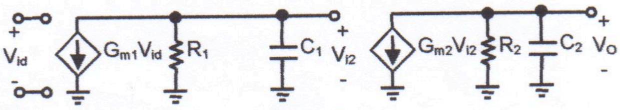


Fig. P4(a)

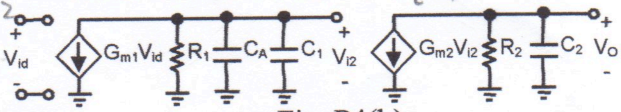


Fig. P4(b)

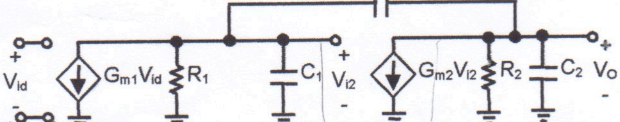


Fig. P4(c)

$\frac{g_{m1}}{C_L} \times V_{ov1}$

(15%) 5. A folded-cascode OPAMP is shown in Fig. P5, where $I_{M11} = 100\mu A$, $I_{M9} = I_{M10} = 300\mu A$, and $|V_{OV}|$ for all transistors is 0.2 V. Assume $V_{DD} = 3.3$ V, $V_{tn} = 0.7$ V, $|V_{tp}| = 0.8$ V, and $C_L = 1$p F, please find

(a) input common-mode range. (5%)

(b) slew rate. Explain your answer. (10%)

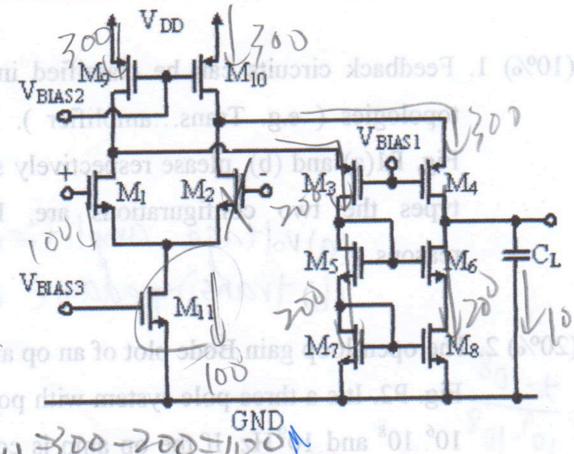


Fig. P5

(a) $1.1 \le V_{ICM} \le 3.8V$

(b) Let $M_1 = ON, M_2 = OFF$

$\therefore I_{D3} = 300 - 100 = 200$

$I_{D4} = 300$

$\because$ current mirror $I_{D8} = 200$

$SR = \frac{100 \times 10^{-6}}{1 \times 10^{-12}} = 100\ V/\mu s$

$\therefore I_{C_L} = 300 - 200 = 100$ $\therefore SR = 100\ V/\mu s$

(20%) 6. A cascode current mirror is shown in Fig. P6(a), and a wide-swing current mirror is shown in Fig. P6(b). The $|V_{OV}|$ for all transistors is 0.2 V and the $|V_t|$ is 0.7 V. All transistors are identical.

(a) Please calculate V_{bias1}, V_{bias2} and the minimum value of V_O in Fig. P6(a). (10%)

(b) Please calculate V_{bias3}, V_{bias4} and the minimum value of V_O in Fig. P6(b). (10%)

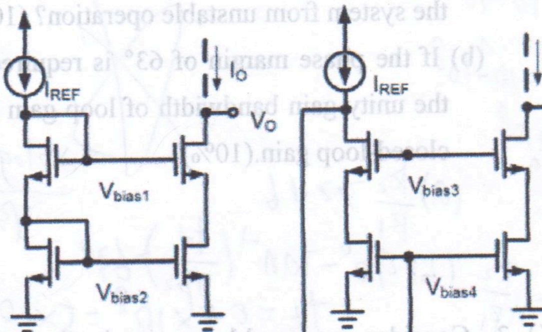


Fig. P6(a) Fig. P6(b)

$V_{ov}+V_t+V_{ov}+V_t-V_t$

$V_{ov}+V_{ov}+V_t$

(a) $V_{O(min)} = V_t + 2V_{ov} = 1.1(V)$

$V_{BIAS1} = V_{O(min)} + V_t = 1.8(V)$

$V_{BIAS2} = V_t + V_{ov} = 0.9(V)$

(b) $V_{O(min)} = 2V_{ov} = 0.4(V)$

$V_{BIAS3} = V_{O(min)} + V_t = 1.1(V)$

$V_{BIAS4} = V_t + V_{ov} = 0.9V$

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(16%) 1. With less than 25 words, please list the name of the **four feedback amplifiers** (e.g. Trans… amplifier) and their **corresponding topologies** (e.g. series-shunt). (16%)

(a) $|A\beta| = \mu \cdot \frac{R_L \| (R_1+R_2)}{r_o + R_L \| (R_1+R_2)} \cdot \frac{R_1}{R_1+R_2} = 6000 \cdot \frac{1}{3} \times \frac{1}{2} = 1000 V/V$

$f_{P1} = \frac{1}{2\pi\, r_{out}\, C_L} = 4.77MHz$

(20%) 2. Consider a closed-loop circuit shown in Fig. P2. Assume that the input impedance of the basic amplifier is **infinite**, open-loop gain μ=6000 V/V, r_o=R_L=100 kΩ, R_1 = R_2 = 50kΩ, C_L=1pF, please **respectively** calculate the **dc gain of the loop gain**, and the **dominant pole location of the loop gain** by

(a) breaking the loop **at** ***XX'***. (10%)

(b) breaking the loop **at the output of the basic amplifier** ***Y***. (10%)

1000V/V

4.77MHz

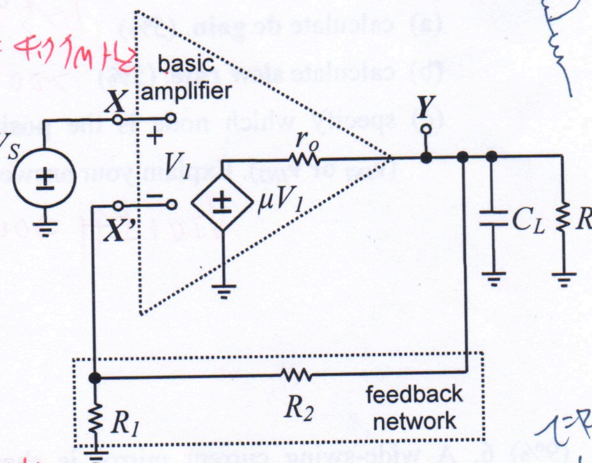
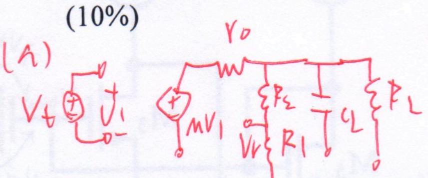
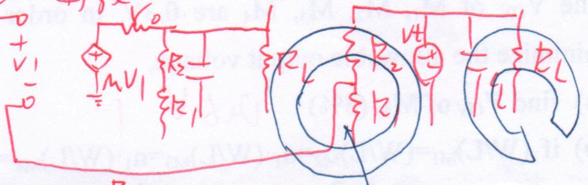


Fig. P2

(A)



(b).



$|A\beta| = \frac{R_1}{R_1+R_2} \mu \cdot \frac{R_L \| (R_1+R_2)}{r_o + R_L \| (R_1+R_2)} = 1000 V/V$

$V_{ov} = V_{GS} - V_t$

(20%) 3. Please give definitions of the following terms for an op amp.

(a) -3dB bandwidth (5%) (b) unity-gain bandwidth (5%) (c) CMRR (5%) (d) PSRR (5%)

$PSRR^+ = \frac{A_d}{A^+}$ $A^+ = \frac{v_o}{v_{dd}}$

$PSRR^- = \frac{A_d}{A^-}$ $A^- = \frac{v_o}{v_{gnd}}$

$I = \frac{1}{2} k_n' \left(\frac{W}{L}\right)(V_{GS} - V_t)^2$

(20%) 4. Fig. P4 shows a two-stage op amp with a simple bias circuit. Assume $\mu_n C_{ox}$=200μA/V², $\mu_p C_{ox}$=80μA/V², $|V_{tp}|$=0.8V, and I_{D8}=20μA, I_{D5}=200μA, I_{D7}=500μA, and $(W/L)_{M5}$=(20μm/1μm), $(W/L)_{M7}$=(50μm/1μm), $(W/L)_{M3}$=(10μm/1μm). Without considering the channel-length modulation, please

(a) calculate $\mathbf{(W/L)_{M8}}$. (5%) 2um/1um

(b) calculate $\boldsymbol{R_b}$. (5%) 100kΩ

(c) design the $\mathbf{(W/L)_{M6}}$ to minimize the input systematic offset if the input stage is perfectly balanced. (5%) 50um/1um.

(d) find the **output swing** of the op amp. (5%)

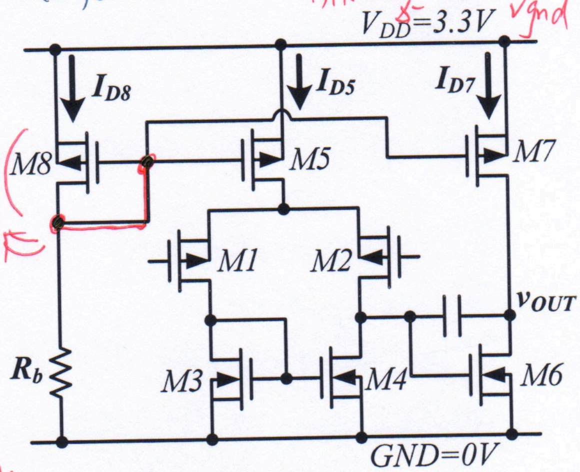


Fig. P4

$0.316 \approx V_{ov6} \le V_{out} \le V_{DD} - V_{ov7} = 2.8V$.

(15%) 5. A folded-cascode op amp is shown in Fig. P5 where I_{M11}=200μA, I_{M10}=300μA, and $|V_{OV}|$ for all transistors is 0.2V. Assuming λ_n=0.1V^{-1}, λ_p=0.2V^{-1}, V_{DD}=3.3V, V_{tn}=0.8V, $|V_{tp}|$=0.8V, and C_L=1pF, please

(a) calculate **dc gain**. (5%) 675 V/V

(b) calculate **slew rate**. (5%) 200 V/μs

(c) specify which node is the **positive** input terminal (***v_{IN1}* or *v_{IN2}***). Explain your answer. (5%) V_{IN1}

V_{IN1}上升 ⇒ output 也上升

V_{IN1}為 positive

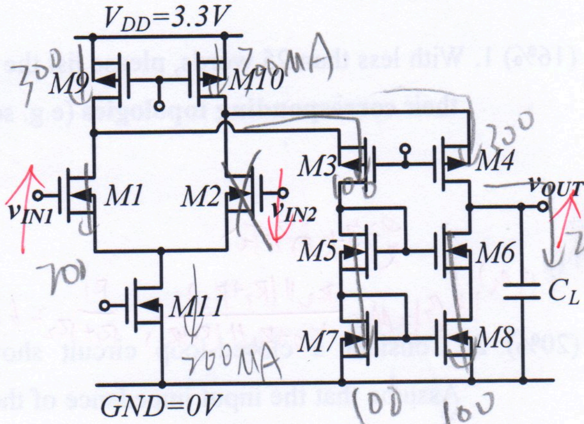


Fig. P5

(9%) 6. A wide-swing current mirror is shown in Fig. P6. Assume V_{tn}=0.7V for all transistors, and $I_{bias}=I_{in}=I_{out}$. The V_{OV} of M_1, M_2, M_3, M_4 are 0.3V. In order to minimize the allowable output voltage,

(a) find **V_{OV} of M_5**. (3%) 0.6V

(b) if $(W/L)_{M1}=(W/L)_{M2}=n_1\cdot(W/L)_{M3}=n_1\cdot(W/L)_{M4}=n_2\cdot(W/L)_{M5}$, what are the values of $\mathbf{n_1}$ and $\mathbf{n_2}$ should be designed? (6%) 1 4

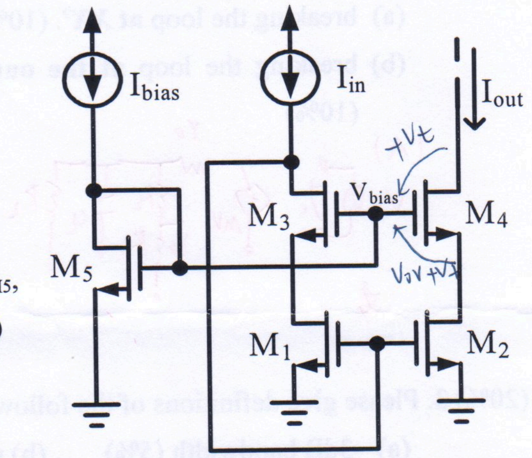


Fig. P6

$I \propto \left(\frac{W}{L}\right)\cdot V_{OV}^2$

$\because I_{bias}=I_{in}=I_{out} \wedge V_{OV5}=2\cdot V_{OV\,1\sim4}$

$\left(\frac{W}{L}\right)_5 \times 0.36=\left(\frac{W}{L}\right)_3 \times 0.09$

$4\left(\frac{W}{L}\right)_5=\left(\frac{W}{L}\right)_3$

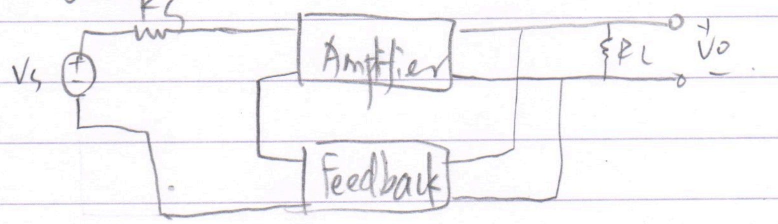
楊喬棟

電子學(三)

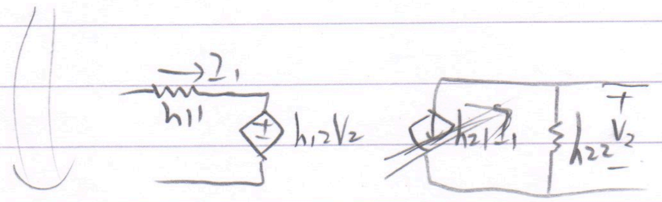
2007. 考古. solution

1. (a) voltage amplifier: series-shunt
current amplifier: shunt-series
transconductance amplifier: series-series
transimpedance amplifier: shunt-shunt

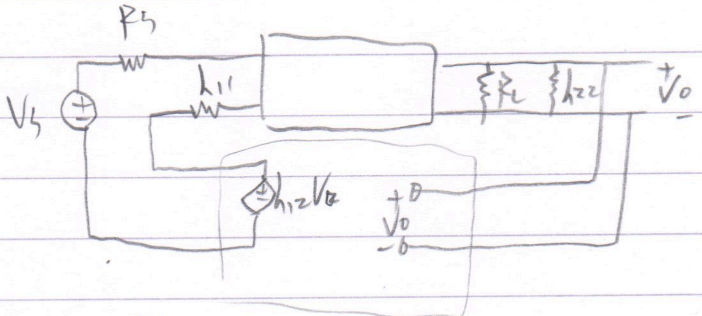
(b). voltage amplifier ⇒ series-shunt ⇒ h parameter.



$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

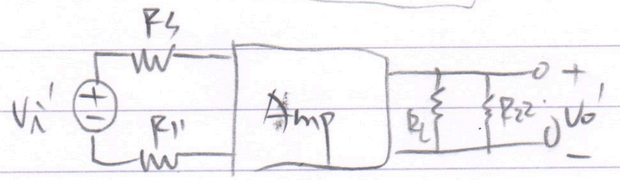


$$\begin{cases} V_1 = h_{11} I_1 + h_{12} V_2 \\ I_2 = h_{21} I_1 + h_{22} V_2 \end{cases}$$

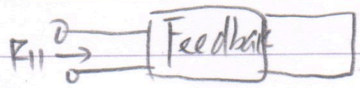


$$\beta = \left.\frac{V_1}{V_2}\right|_{I_1=0} = h_{12}$$

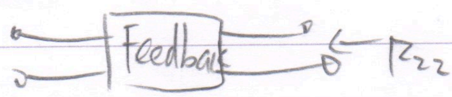
$$A = \frac{V_o'}{V_i'}$$

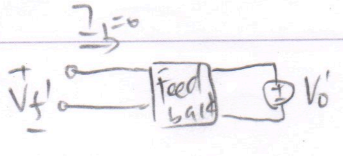


R_{11} ⇒



R_{22} ⇒



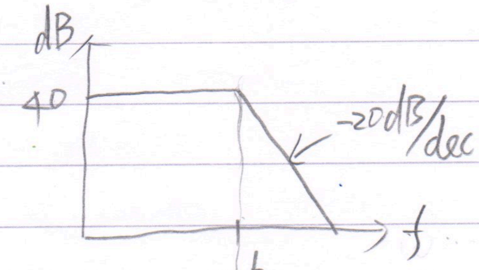


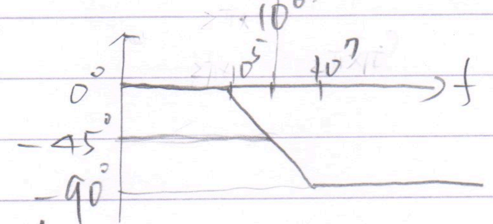
$$\beta = \left.\frac{V_f'}{V_o'}\right|_{I_1=0}$$

楊喬棟

2. (a)

$$A(s) = \frac{100}{1+\frac{jf}{10^6}}$$





(b) negative feedback

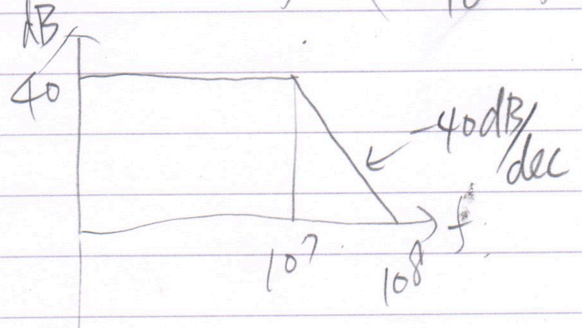
$$\beta = \frac{9}{91+9} = 0.09$$

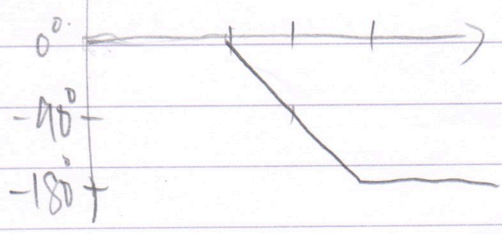
(c) $$A_F(s) = \left(\frac{A}{1+A\beta}\right)^2 = \left(\frac{\frac{100}{1+\frac{jf}{10^6}}}{1+\frac{9}{\frac{1+jf}{10^6}}}\right)^2 = \left(\frac{\frac{100}{\frac{10^6+jf}{10^6}}}{1+\frac{9}{\frac{10^6+jf}{10^6}}}\right)^2 = \left(\frac{\frac{10^8}{10^6+jf}}{1+\frac{9\times10^6}{10^6+jf}}\right)^2$$

$$= \left(\frac{10^8}{10^6+jf+9\times10^6}\right)^2 = \left(\frac{100}{10+\frac{jf}{10^6}}\right)^2 = \left(\frac{10}{1+\frac{jf}{10^7}}\right)^2 = \frac{100}{1+\frac{2jf}{10^7}+\frac{(jf)^2}{10^{14}}}$$

$f_1 f_2$

$\frac{1}{f_1}+\frac{1}{f_2}$ $\quad f_1 = f_2 = 10^7$





(d) $$A_f'(s) = \left(\frac{A'}{1+A'\beta}\right)^2 = \left(\frac{0.8A}{1+0.8\beta A}\right)^2$$

$$A_F = \frac{A}{1+A\beta} = \frac{0.8\times100}{1+0.8\times100\times0.09} = 9.756$$

$$\frac{10-9.756}{10} = 2.44\%$$

楊喬棟

3. Slew Rate: The maximum rate of change possible at the output of the op amp.

p136

which is defined as $SR = \left.\frac{dV_o}{dt}\right|_{max}$.

p.130-131

usually specified in units of $V/\mu s$.

Unity-Gain-Bandwidth: the Gain $|A|$ reaches unity (0dB) at the frequency ωt

$f_t = \frac{\omega t}{2\pi}$ is the unity-gain bandwith

rail-to-rail: increase input common-mode range

4.

$$-V_{SS}+V_{ov3}+V_{tn}-V_{tp} \le V_{in} \le V_{DD}-V_{ov}-V_{ov}-V_t$$

$$-1.65+0.35+0.5-0.5 \le V_{icm} \le 1.65-0.35-0.35-0.5$$

$$-1.3V \le V_{Icm} \le 0.45V.$$

$$-V_{SS}+V_{ov6} \le V_o \le V_{DD}-V_{ov7}$$

$$-1.2 \le V_o \le 1.2$$

(b) $g_{m1} = \frac{2(\frac{I}{2})}{V_{ov1}}$

$$r_{o2}//r_{o4} = \frac{1}{\lambda\times\frac{I}{2}} // \frac{1}{\lambda\times\frac{I}{2}} = \frac{2}{\lambda I}//\frac{2}{\lambda I} = \frac{\frac{4}{\lambda^2 I^2}}{\frac{4}{\lambda I}} = \frac{1}{\lambda I} = \frac{A}{I} = \frac{20}{I}$$

$$A_1 = -g_{m1} r_{out} = \frac{-I}{V_{ov1}} \times \frac{1}{\lambda I} = \frac{1}{\lambda V_{ov1}} \cdot \frac{-A}{V_{ov1}} = \frac{-20}{0.2} = -100 V/V.$$

$$A_2 = \frac{2\times 0.45mA}{V_{ov6}} \left(\frac{1}{\lambda 0.45} // \frac{1}{\lambda 0.45}\right) = 40 V/V$$

$$R_o = \frac{1}{\lambda I_D} \qquad \frac{400}{9} // \frac{400}{9} = \frac{200}{9}$$

$$= \frac{20}{0.45} = \frac{400}{9}$$

$A = -g_m r_o$

（國立成功大學論文用紙）