九十三學年度台灣大學電資學院電機系電子學(一)期中考

1. The 7-V zener diode in the circuit of Fig. 1 is specified to have $V_Z = 7V$ at $I_Z = 5mA$, $r_Z = 20\Omega$, and $I_{ZK} = 0.2mA$. The supply voltage V^+ is nominally 10V but can vary by ±1V.

(a) What is the maximum current the zener diode conducts in this design? What is the output voltage of the circuit and the power dissipation of the zener diode under this condition? (9 points)

(b) What is the minimum value of R_L for which the diode still operates in the breakdown region? (4 points)

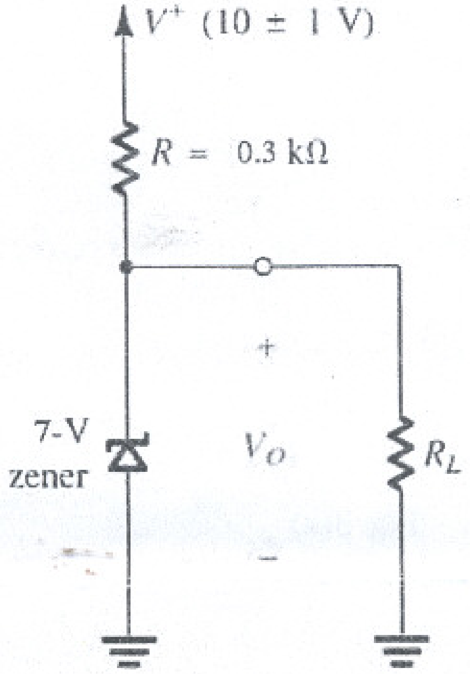

Fig. 1

2. For a Si pn junction operating at 300K, the electron concentration in p-Si is $10^3/cm^3$, and the hole concentration in n-Si is $10^4/cm^3$.

(a) Use $n_i = 1.5 \times 10^{10}/cm^3$ to find the built-in voltage. (Hint: $V_O = V_T \ln (N_A N_D / n_i^2)$ and $V_T = 25mV$). (3 points)

(b) Which side (p side or n side) has larger depletion width? Indicate the polarity of the charge stored in the depletion region of this side. What is the ratio of p-side width to n-side width? (3 points)

3. A is an ideal OP AMP with output saturation voltages at ±4V, R_1=10 KΩ , R_2=500 KΩ, C= 1 nF, V_{OS}=10 mV, $v_s(t)$ is shown in Fig.3(b).

(a) Find v_o at t=0- . (4 points)

(b) Find the max. value of t_1 such that the OP AMP doesn't enter saturation state . (5 points)

(c) Under the condition of (2), plot the output waveform $v_o(t)$ for $0^+ \le t < \infty$. (4 points)

(d) If, in addition to V_{os}, there are bias currents $I_{B1}=I_{B2}$=5 μA, flowing INTO the (+) and (-) input terminals of A. Repeat (a) and (b). (6 points)

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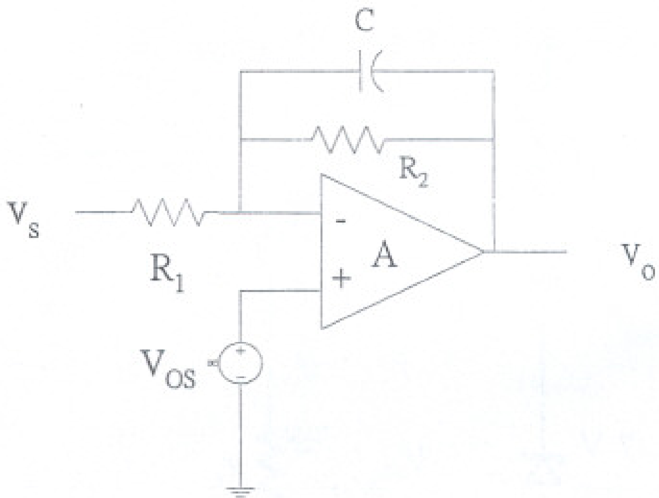


Fig. 3(a)

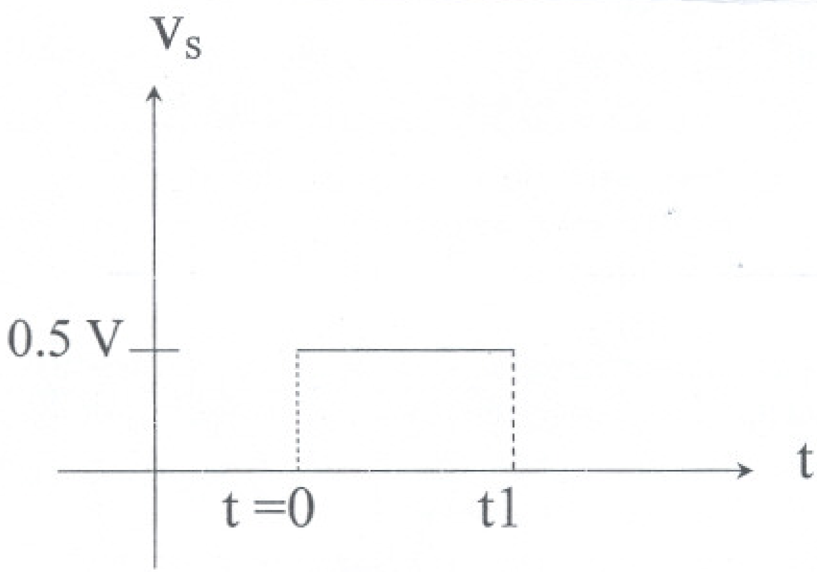


Fig. 3(b)

9 4. (a) Find the value of V_O using constant-voltage-drop model with V_D=0.7V. (10 points)

(b) Assuming a ±10% variation in all of the three power supplies, find the maximum voltage variation (in volt) at the output V_O with V_T=25 mV and n=2. (9 points)

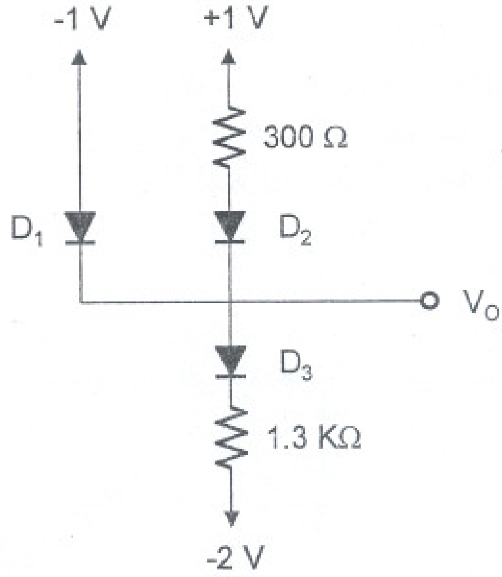


Fig. 4

5. For the circuit shown in the figure below, assuming A_1 and A_2 are ideal Op AMPs and R_a=R_b=R_c=R_d=R_1=R_2=R.

(a) Find the voltage gain $V_o/(V_{I1}-V_{I2})$.(5 points)

(b) What is the input impedance seen by V_{I1} and V_{I2}?(2 points)

(c) If V_{I1}=V_{I2}=V_x, find V_o/V_x. (2 points)

~~(d) What is the CMRR (common-mode rejection ratio) of the circuit?(2 points)~~

(e) If resistor mismatch exists such that R_a=R_b=R_d=R, R_c=R+ΔR (assuming $\Delta R \ll R$), derive an expression for the circuit CMRR.(5 points)

(f) From (e), what is the CMRR value (***in dB***) if R_x=R and ΔR=0.01R. (2 points)

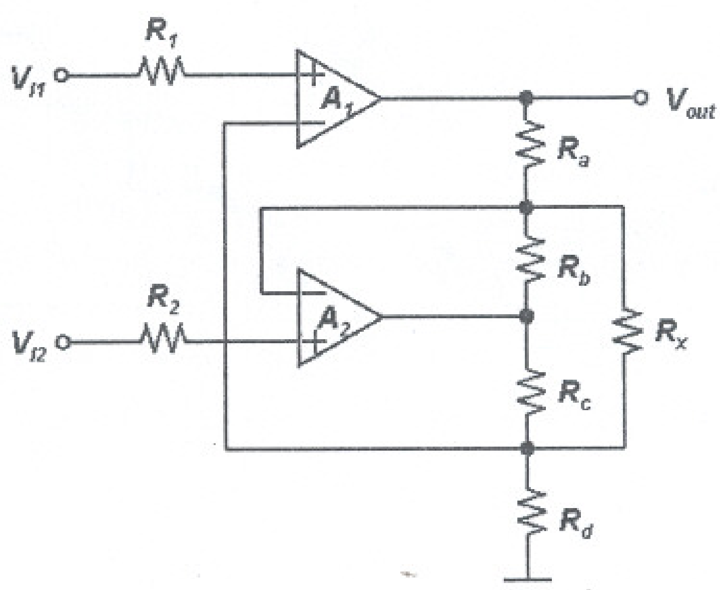


Fig. 5

6. In the circuit shown in Fig. 6, D_1 is a large-area high-current diode whose reverse leakage is high and independent of applied voltage while D_2 is a much smaller, low-current diode for which $n=1$. At an ambient temperature of 20℃, resistor R_1 is adjusted to make $V_{R1}=V_2=520$mV. Subsequent measurement indicates that R_1 is 520 KΩ. Find the saturation current of D_2. What do you expect the voltages V_{R1} and V_2 to become at 0℃ and at 40℃? (13 points)

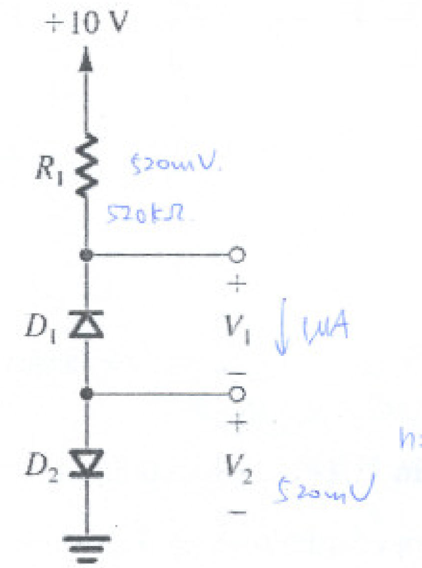


Fig. 6

7. The circuit in Fig. 7 implements a complementary output rectifier. Sketch and clearly label the waveforms of V_o^+ and V_o^-. Assume a 0.7-V drop across each conducting diode. If the magnitude of the average of each output is to be 15 V, find the required amplitude of the sine wave across the entire secondary winding. What is the PIV of each diode? (12 points)

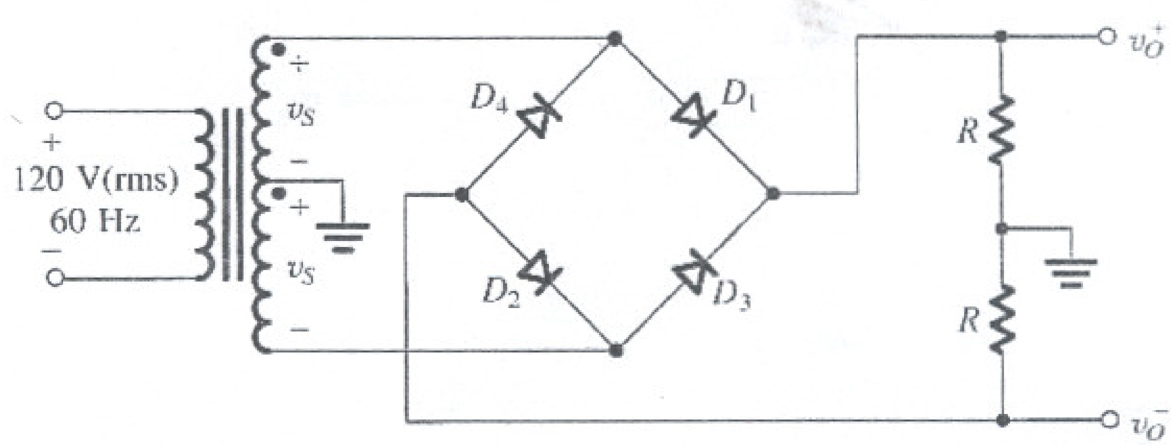
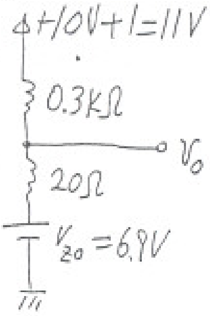


Fig. 7

1. (a)



因為 $V_Z=7V$ @ $I_Z=5mA$

故 $7V = 20\Omega \cdot 5mA + V_{Z0}$; $V_{Z0}=6.9V$

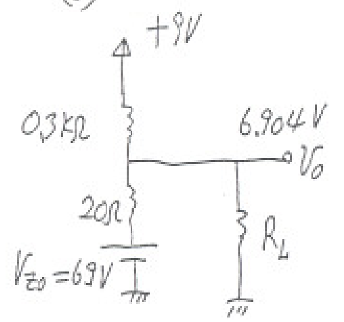
最大电流在负载 $R_L=\infty$，且 $V^+=10+1V$ 時発生

故 $I_Z = \frac{11V-6.9V}{0.32k\Omega} = 12.8mA$ (3)

$V_0 = 12.8mA \cdot 20\Omega + 6.9V = 7.156V$ (3)

$P_D = V_0 \cdot I_Z = 91.6mW$ (3)

(b)



Zener维持在 breakdown 時之最低电流为 $I_{ZK}=0.2mA$

故 $V_Z = 6.9+20\Omega\cdot 0.2mA = 6.904V$

若取 $V^+=9V$ $\quad I_R = \frac{9-6.904}{0.3k\Omega} = \frac{2.096V}{0.3k\Omega} = 6.99mA$

$R_L = \frac{6.904}{6.99-0.2} = 1.017k\Omega$ --- Ans. (4)

若取 $V^+=11V$ $\quad I_R = \frac{11-6.904}{0.3k\Omega} = \frac{4.096V}{0.3k\Omega} = 0.01365A$

$R_L = \frac{6.904}{13.65-0.2} = 513\Omega$ .... 此值雖更小,但要考慮在 V^+所有変動之下都可以維持在 breakdown 故取 $R_L=1.017k\Omega$ 方为正確.

2. (a) p-Si $n=10^3/cm^3$; $p=\frac{n_i^2}{n} \cong \frac{2.25\cdot10^{20}}{10^3} = 2.25\cdot10^{17}/cm^3$ N_A

n-Si $p=10^4/cm^3$; $n=2.25\cdot10^{16}/cm^3$ N_D

$0.025 \ln \frac{10^3\cdot10^4}{(1.5\times10^{10})^2}$

$V_0 = 25mV\cdot\ln\frac{2.25\cdot10^{17}\cdot 2.25\cdot10^{16}}{(1.5\cdot10^{10})^2} = 25mV\cdot\ln 2.25\cdot10^{13} = \underline{0.769V}$

(b) n-side N_D 比較低故 n-side depletion region 較寬.

n-side depletion region 内的 charge 为 positive (正 charge)

(p-side width)/(n-side width) = 1/10 与摻雜濃度成反比.

3. A is an ideal OP AMP with output saturation voltages at ±4V, R_1=10 KΩ, R_2=500 KΩ, C= 1 nF, V_{OS}=10 mV, $v_s(t)$ is shown in Fig.3(b).

(a) Find v_o at t=0- . (4 points) $V_{os}(1+\frac{R_2}{R_1})$ 0.51V

(b) Find the max. value of t_1 such that the OP AMP doesn't enter saturation state . (5 points)

(c) Under the condition of (b), plot the output waveform $v_o(t)$ for $0^+ \le t < \infty$. (4 points) b

(d) If, in addition to V_{os}, there are bias currents $I_{B1}=I_{B2}$=5 μA, flowing INTO the (+) and (-) input terminals of A. Repeat (a) and (b). (6 points)

2.5V + 0.51V = 3.01V

$0.5ms \ln \frac{25}{19.99} = 0.1645ms$

$\frac{V_s-V_{os}}{R_1}+\frac{V_o-V_{os}}{R_2}+C\frac{d}{dt}(V_o-V_{os})=0$

$\frac{dV_o}{dt}+\frac{V_o}{R_2C}=(\frac{1}{R_1C}+\frac{1}{R_2C})V_{os}-\frac{V_s}{R_1C}$

$\tau = 0.5ms$

$V_o=-24.49+25e^{-\frac{t}{\tau}} \ge -4$

$e^{-\frac{t}{\tau}} \ge \frac{20.49}{25}$

$t \le \tau \ln \frac{25}{20.49}$

$t_1 = 0.5ms \cdot 0.1989 = 99.47\mu s$

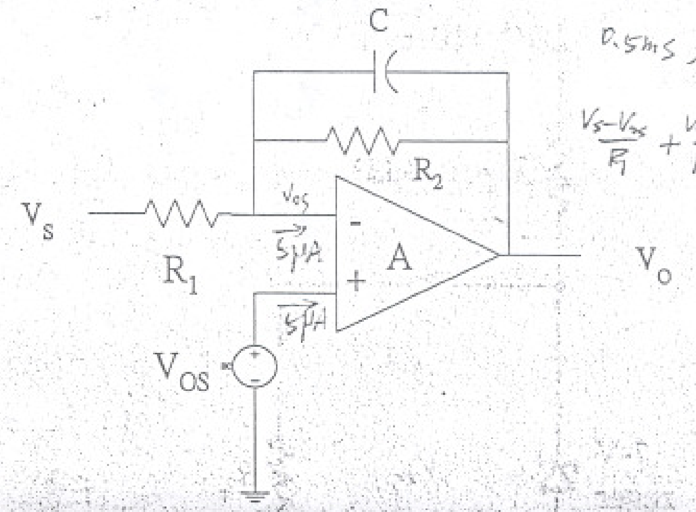


Fig. 3(a)

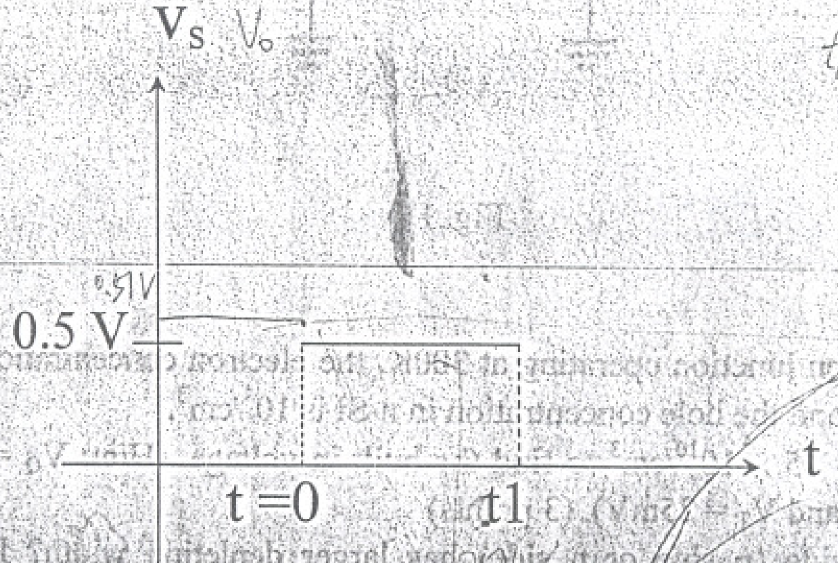


Fig. 3(b)

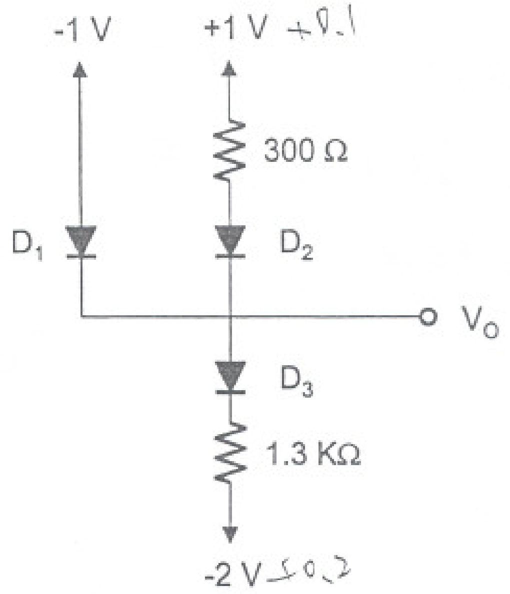
4. (a) Find the value of V_O using constant-voltage-drop model with V_D=0.7V. (10 points) 0

(b) Assuming a ±10% variation in all of the three power supplies, find the maximum voltage variation (in volt) at the output V_O with V_T=25 mV and n=2. (9 points) 0.12V

2004 Midterm

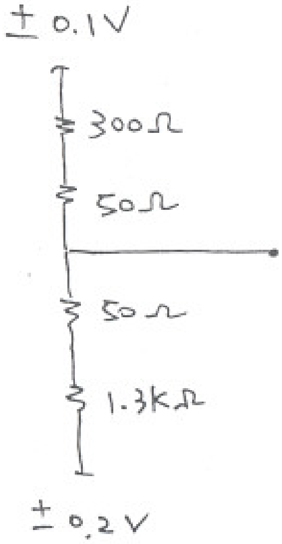
(a) Find the value of V_O utilizing constant-voltage-drop model with V_D=0.7V. (10 pt)

(b) Assuming a ±10% variation in all of the three power supplies, find the maximum voltage variation (in volt) at the output V_O with V_T=25 mV and n=2. (9 pt)



D_1 off. D_2, D_3 ON $\longrightarrow$ $V_o = 0V$

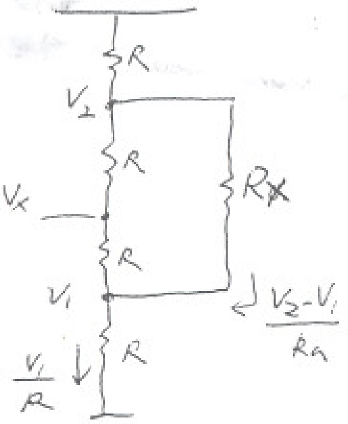
$I_{D1} = I_{D2} = 1mA$.



$r_{d1} = r_{d2} = \frac{2\times25}{1} = 50\Omega$

$\Delta V_o = \pm\left(\frac{1350}{1700}\times0.1 + \frac{350}{1700}\times0.2\right)$

$= \pm\ 0.12V\ (0.1206)$



$$v_x = \left(\frac{V_1}{R} - \frac{V_2-V_1}{R_x}\right)\times R + V_1 = 2V_1 - \frac{V_2-V_1}{R_x}\cdot R$$

$$V_o = V_2 + R\cdot\left(\frac{V_2-V_x}{R} + \frac{V_2-V_1}{R_x}\right)$$

$$= V_2 + \frac{V_2-V_1}{R_x}\cdot R + \left(V_2 - 2V_1 + \frac{V_2-V_1}{R_x}\cdot R\right)$$

$$= 2V_2 - 2V_1 + 2\frac{R}{R_x}(V_2-V_1)$$

$$= (V_2-V_1)\cdot\left(2+\frac{2R}{R_x}\right)$$

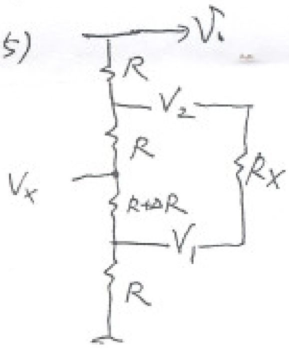
$$\Rightarrow \frac{V_o}{V_1-V_2} = \underline{-\left(2+\frac{2R}{R_x}\right)}$$

b (2) ∞, ∞

c (3) 0

d (4) ∞

e (5)



$$\cancel{V_x = V_1 + \frac{V_1}{R}(R+\Delta R) = 2V_1 + V_1\frac{\Delta R}{R}}$$

$$\cancel{V_o = V_2 + \frac{V_2-V_x}{R}\times R = 2V_2 - 2V_1 + V_1\frac{\Delta R}{R}}$$

$$V_x = \left(\frac{V_1}{R} - \frac{V_2-V_1}{R_x}\right)\cdot(R+\Delta R) + V_1 = 2V_1 + V_1\cdot\frac{\Delta R}{R} - \frac{V_2-V_1}{R_x}(R+\Delta R)$$

$$V_o = V_2 + R\left(\frac{V_2-V_x}{R} + \frac{V_2-V_1}{R_x}\right)$$

$$= V_2 + \frac{V_2-V_1}{R_x}\cdot R + V_2 - 2V_1 - V_1\frac{\Delta R}{R} + \frac{V_2-V_1}{R_x}(R+\Delta R)$$

$$= 2V_2 - 2V_1 + \frac{V_2-V_1}{R_x}\cdot R + \frac{V_2-V_1}{R_x}R + \frac{V_2-V_1}{R_x}\Delta R - V_1\frac{\Delta R}{R}$$

$$\Rightarrow V_o = (V_2-V_1)\left(2+\frac{2R+\Delta R}{R_x}\right) \Rightarrow \frac{V_o}{V_1-V_2} = -\left(2+\frac{2R+\Delta R}{R_x}\right)$$ (Assume $\Delta R \ll R$)

for $V_1 = V_2 = V_{CM}$,

$$V_x = V_{cm} + \frac{V_{cm}}{R}(R+\Delta R) = 2V_{cm} + V_{cm}\frac{\Delta R}{R}$$

$$V_o = V_{cm} + \frac{V_{cm}-V_x}{R}\times R = 2V_{cm} - V_x = V_{cm}\frac{\Delta R}{R}$$

$$\Rightarrow \frac{V_o}{V_{cm}} = \frac{\Delta R}{R} \rightarrow CMRR \cong \left|\frac{2+2R/R_x}{\Delta R/R}\right|$$

4b) $R_x = R$, $\Delta R = 0.01R$

$$CMRR = \frac{4}{0.01} = 400 = \underline{\cancel{46}\ 52\ dB}$$