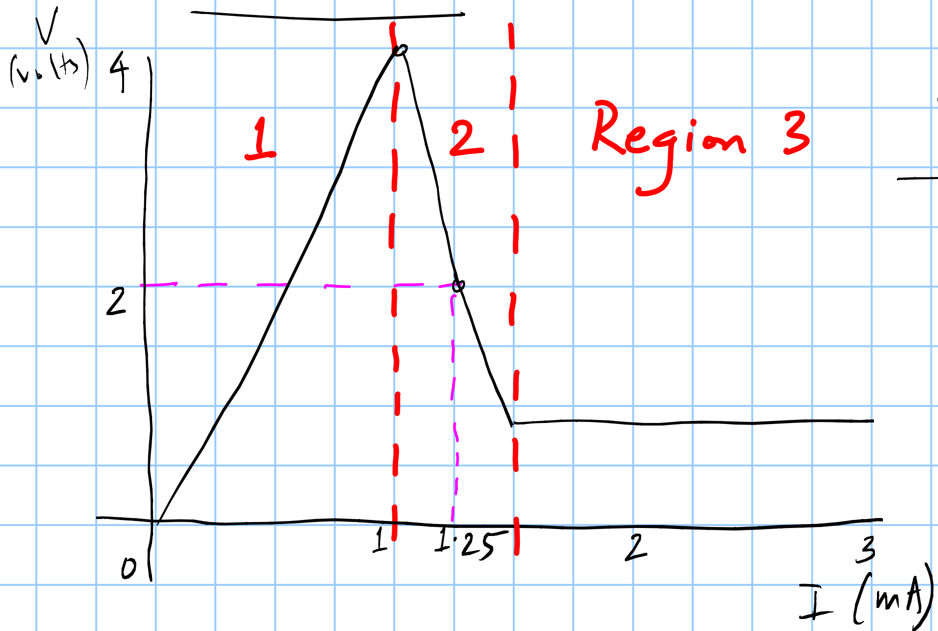
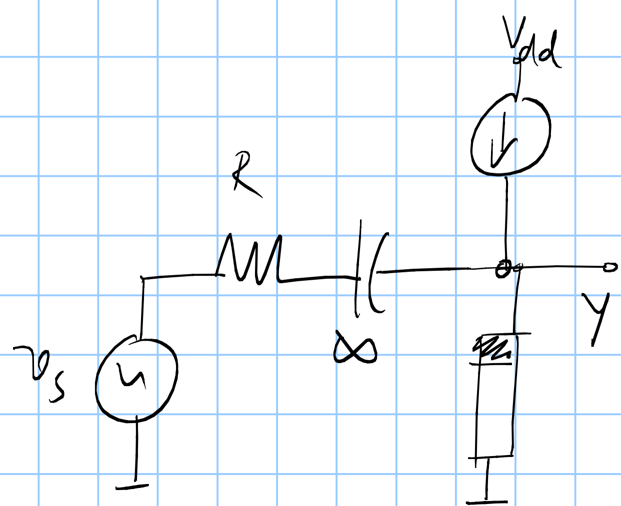
Note Title 9/23/2007

SOLUTIONS TO QUIZ 1

Problem 1

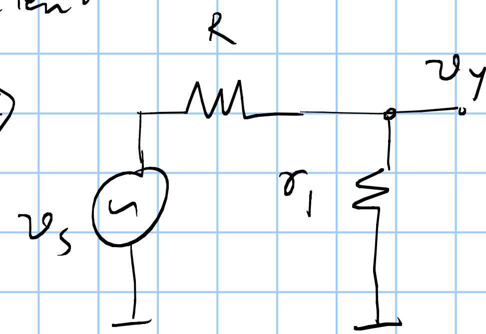


Region	Slope $\left(\frac{V}{mA}\right)$
1	4
2	−8
3	0



Amplifier

Incremental Equivalent ⟹



r_1 is the incremental resistance of the wormister

$$\text{Incremental gain} = \frac{v_y}{v_s} = \frac{r_1}{r_1 + R}$$

Part (a) : To get incremental gain, r_1 must be NEGATIVE

⟹ Must bias the wormister in Region 2

Part (b): Want gain of -4

$$\Rightarrow \quad -4 = \frac{r_1}{r_1 + R} \quad \Rightarrow \quad -4r_1 - 4R = r_1$$

$$\Rightarrow \quad R = -1.25\, r_1$$

From the V-I characteristics, $r_1 = -8K$

$$\Rightarrow \quad R = 10K\Omega$$

Part (c): Swing limit computation

The incremental gain is -4

Let V_o be the quiescent voltage at Y

The total voltage at Y is

$$\underbrace{V_o}_{\text{Quiescent}} + \underbrace{(-4)v_s}_{\text{Incremental}}$$

To maximize output swing without distorting, the output sinewave must JUST begin to clip at BOTH extremes

$$\Rightarrow \quad V_o + 4v_A = 0.8 \text{ Volts}$$

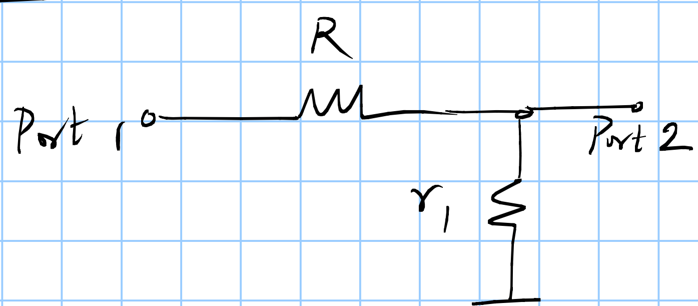
$$\& \quad V_o - 4v_A = 4 \text{ Volts}$$

$$\Rightarrow \quad V_o = \frac{0.8 + 4}{2} = 2.4 \text{ Volts}$$

A quiescent voltage of 2.4 Volts maximizes output swing. This corresponds to a quiescent current of $1\,mA + \dfrac{(2.4-4)}{-8\,V/mA} = 1.2\,mA$

$I = 1.2\,mA$ maximizes the output swing

Part (d) Incremental 2 port parameters



Denote

$G = 1/R$, $g_1 = 1/r_1$

$$y_{11} = G \qquad y_{12} = -G$$

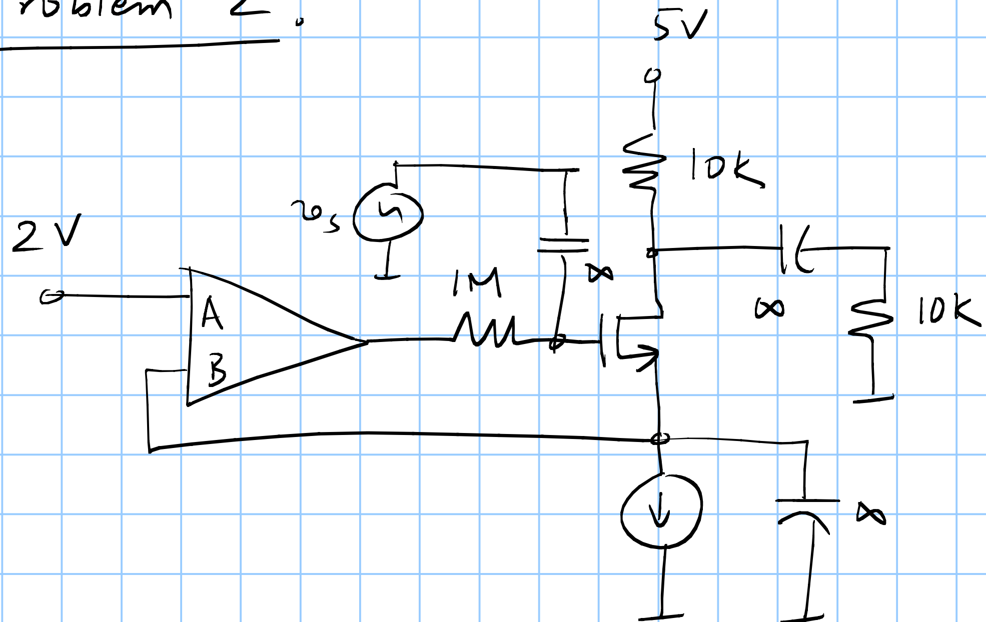
$$y_{21} = -G \qquad y_{22} = g_1 + G$$

$\Rightarrow$ $y_{11} = 0.1\,mS$ $\quad y_{12} = -0.1\,mS$ $\quad y_{21} = -0.1\,mS$

$$y_{22} = -0.125\,mS + 0.1\,mS = -0.025\,mS$$

$$Y = \begin{bmatrix} 0.1\,mS & -0.1\,mS \\ -0.1\,mS & -0.025\,mS \end{bmatrix}$$

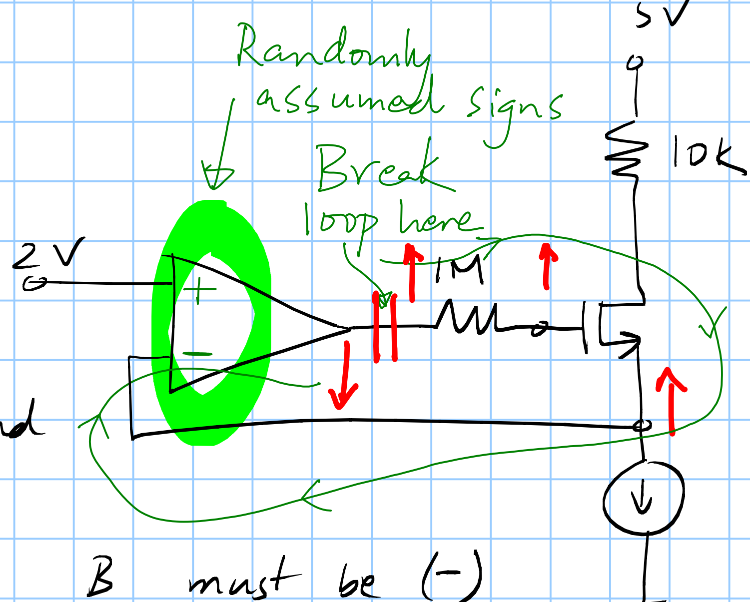
Problem 2:



Part (a)

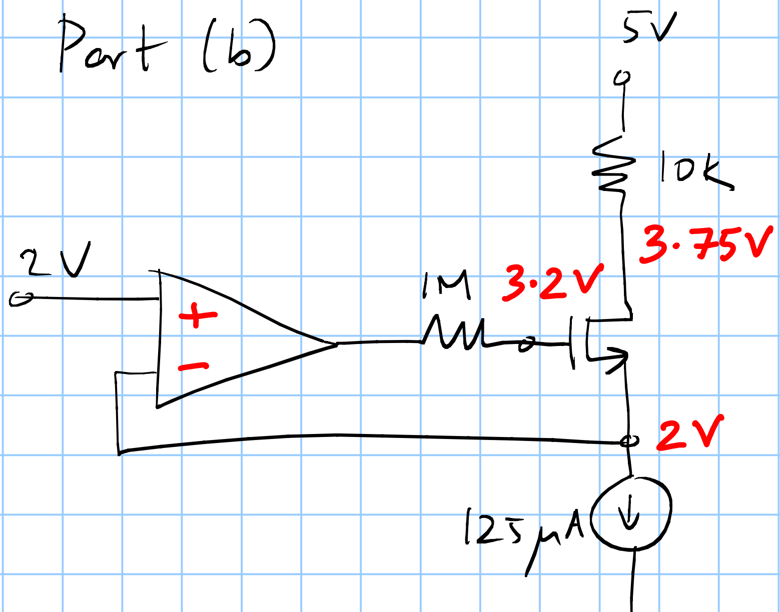
Determining the signs on the opamp

Break loop at a convenient location and go around the loop



⇒ A must be (+) B must be (−)

Part (b)



Circuit for calculating operating point

$V_T = 0.7V$ $\frac{W}{L} = 10$

$\underbrace{k}_{\mu_n C_{ox}} = 100\ \mu A/V^2$

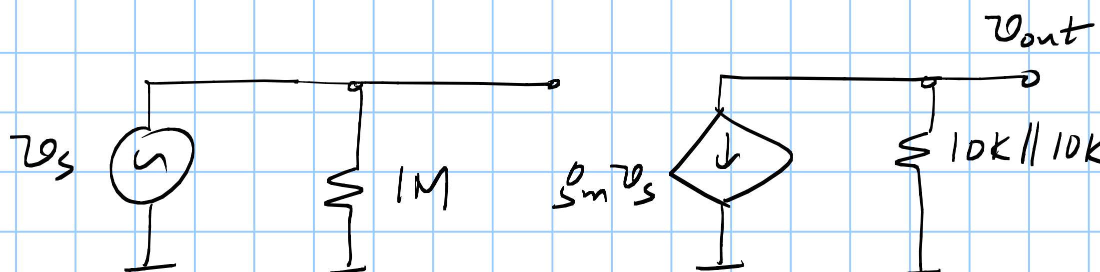
$$\frac{1}{2}\,100\frac{\mu A}{V^2}\;10\left(V_{GS}-0.7\right)^2 = 125\mu A$$

$$\Rightarrow \left(V_{GS}-0.7\right)^2 = \frac{125}{500} \Rightarrow V_{GS} = 0.7 + 0.5\,V$$

$$\Rightarrow V_G = 2V + V_{GS} = 3.2\,V$$

$$V_D = 5V - 125\mu A \cdot 10k = 3.75\,V$$

Part (b) Incremental equivalent circuit



$$\text{Incremental gain} = \frac{v_{out}}{v_s} = -g_m(5k)$$

$$g_m = \frac{2I}{V_{GS}-V_T} = \frac{250\,\mu A}{0.5\,V} = 500\,\mu S$$

$$\Rightarrow \frac{v_{out}}{v_s} = -2.5$$

Part (c) Limit for cutoff

$$v_{max,1} = \frac{I}{g_m} = \frac{125\,\mu A}{500\,\mu S} = 0.25\text{ Volts}$$

Limit for saturation

Total drain voltage $= 3.75 - 2.5\,v_A \sin\omega t$

Total gate voltage $= 3.2 + v_A \sin\omega t$

$$\Rightarrow \quad 3.75 - 2.5\,v_A = 3.2 + v_A - V_T$$

$$\Rightarrow v_A = \frac{3.75 + 0.7 - 3.2}{3.5} = \frac{1.25}{3.5} \approx 0.3 \text{ Volts}$$

$\Rightarrow$ Maximum input amplitude for distortion free operation is

$$\underline{\min\{0.25 \text{ volts}, \ 0.3 \text{ volts}\} = 0.25\text{V}}$$