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University of California at Berkeley
Electrical Engineering and Computer Science
EE105 Midterm Examination #1
Feb. 25, 2016
(80 minutes)

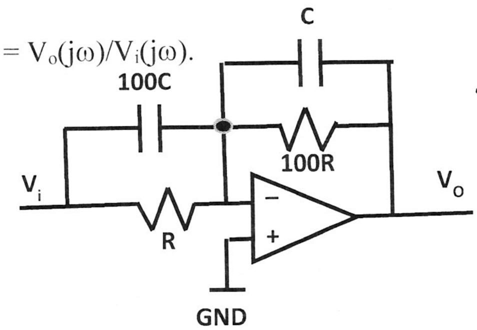
CLOSED BOOK; One standard 8.5" x 11" sheet of notes (both sides) permitted

- Read each problem completely and thoroughly before beginning to work on it
- Summarize all your answers in the boxes provided on these exam sheets
- Show your work in the space provided so we can check your work and scan for partial credit
- Remember to put your name in the space above

Problem #	Points Possible	Score
1	30	30
2	35	35
3	35	35
Total	100	100

1. (30 points) Frequency response. Assume an ideal opamp.

(a) (10 points) Derive the small-signal transfer function, $H(j\omega) = V_o(j\omega)/V_i(j\omega)$.



$$H(j\omega) = -\frac{Z_2(j\omega)}{Z_1(j\omega)}$$

$$\therefore H(j\omega) = \frac{-100\,(1+j\omega(100RC))}{(1+j\omega(100RC))}$$

$$Z_1(j\omega) = \frac{R}{1+j\omega(100RC)}$$

$$Z_2(j\omega) = \frac{100R}{1+j\omega(100RC)}$$

$H(j\omega)$ =	$-100\left[\frac{1+j\omega(100RC)}{1+j\omega(100RC)}\right] = -100$ (pole-zero cancel)

(b) (10 points) Determine the pole(s) and zero(s) frequencies. (Note: Be careful with ω versus f)

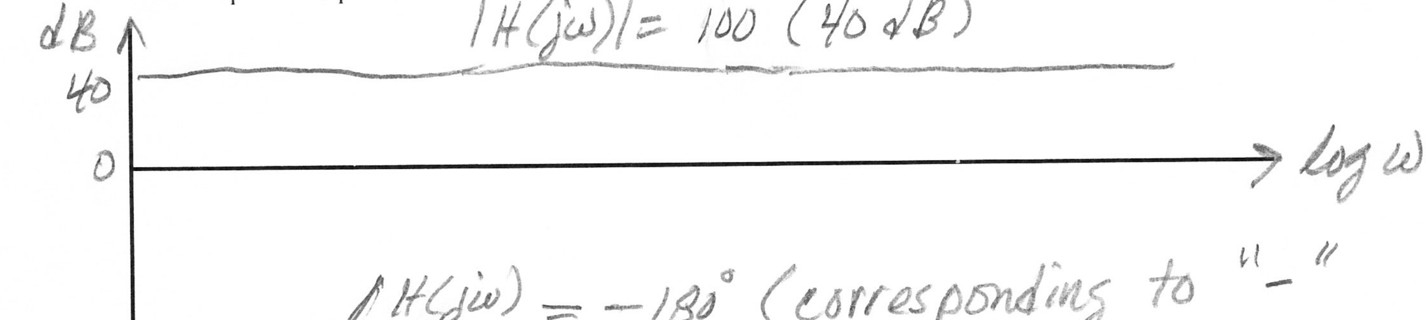
Zero freq: $\omega_z(100RC) = 1 \Rightarrow \omega_z = \frac{1}{100RC}$ rad/sec

Pole freq: $\omega_p(100RC) = 1 \Rightarrow \omega_p = \frac{1}{100RC}$ rad/sec

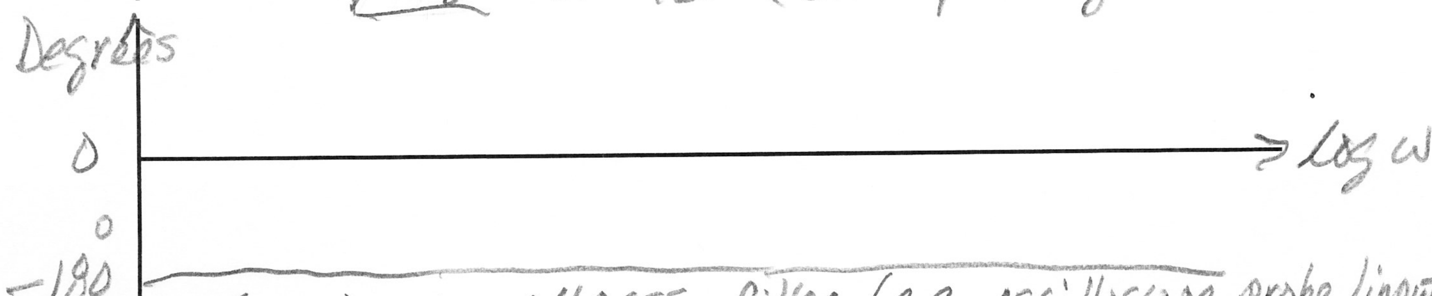
Pole-zero cancellation $\Rightarrow H(j\omega) = -100$ (40 dB)

(c) (10 points) Sketch the Bode magnitude and phase plots (label all constant gain and phase levels and all breakpoint frequencies.

$|H(j\omega)| = 100$ (40 dB)



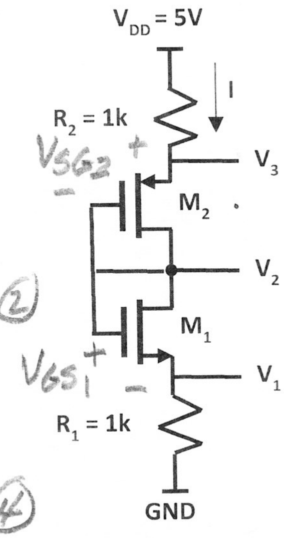
$\angle H(j\omega) = -180^\circ$ (corresponding to "–"



This is an allpass filter (e.g., oscilloscope probe/input)

2. (35 points). CMOS bias calculations. For the NMOS, $V_{tn} = 0.7$ V, $k_n = 1.5$ mA/V^2, and $\lambda_n = 0$. For the PMOS, $V_{tp} = -0.7$ V, $k_p = 0.5$ mA/V^2, and $\lambda_p = 0$.

Find the values of I, V_1, V_2, and V_3.



- Overall, 4 equations in 4 unknowns:

$I = \frac{V_1}{R_1} = \frac{V_1}{1K} \cdots (1)$; $I = \frac{k_n}{2}(V_{GS_1} - V_{tn})^2$

$I = \frac{k_p}{2}(V_{SG_2} - |V_{tp}|)^2 \quad = \frac{k_n}{2}(V_2 - V_1 - 0.7)^2 \cdots (2)$

$= \frac{k_p}{2}(V_3 - V_2 - 0.7)^2 \cdots (3)$; $I = \frac{V_{DD} - V_3}{R_2}$

Now, consider (2) and (3): $\quad = \frac{V_{DD} - V_3}{1K} \cdots (4)$

$I = \frac{k_n}{2}(V_{GS_1} - 0.7)^2 = \frac{k_p}{2}(V_{SG_2} - 0.7)^2 \Rightarrow V_{SG_2} = 1.73\, V_{GS_1} - 0.51 \cdots (5)$

KVL $\Rightarrow IR_1 + V_{GS_1} + V_{SG_2} + IR_2 = V_{DD}$

Thus, $I = \frac{V_{DD} - V_{GS_1} - V_{SG2}}{2K} = 10^{-3}(2.76 - 1.37 V_{GS_1}) \cdots (6)$

Equate (6) to (2):

$10^{-3}(2.76 - 1.37 V_{GS_1}) = 0.75 \times 10^{-3}(V_{GS_1} - 0.7)^2$

$1.33(2.76 - 1.37 V_{GS_1}) = V_{GS_1}^2 - 1.4 V_{GS_1} + 0.49$

$\Rightarrow V_{GS_1}^2 + 0.42 V_{GS_1} - 3.18 = 0$

$\Rightarrow V_{GS_1} = \frac{-0.42 \pm 3.59}{2} = \boxed{1.59\text{ V}}$ or -2.01 V

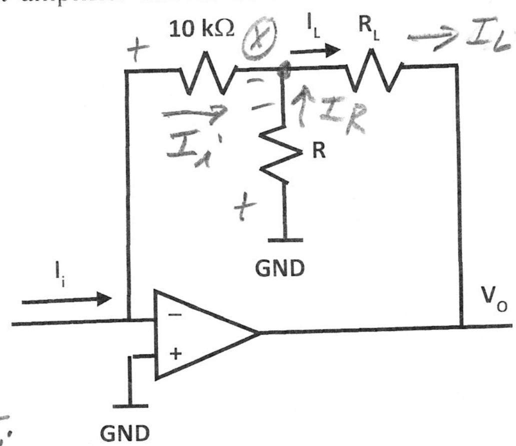
$V_{SG_2} = 1.73 V_{GS_1} - 0.51 = \boxed{2.24\text{ V}}$

$I = \frac{V_{DD} - V_{GS_1} - V_{SG2}}{2K} = \boxed{0.59\text{ mA}}$

$\boxed{V_1 = IR_1 = 0.59\text{ V}}$; $\boxed{V_3 = V_{DD} - IR_2 = 4.41\text{ V}}$; $\boxed{V_2 = V_3 - V_{SG2} = 2.17\text{ V}}$

I = 0.59 mA	V_1 = 0.59 V	V_2 = 2.17 V	V_3 = 4.41 V

3. (35 points) Assuming an ideal opamp, design the current amplifier shown below to have a current gain of $I_L/I_i = 11$ A/A.



$\Rightarrow I_L = 11 \cdot I_i$

(a) Find the required value for *R*.

Note: $\frac{I_L}{I_i} = 11 \Rightarrow I_L = 11 I_i$

KCL @ ⓧ: $I_i + I_R = I_L = 11 I_i$

$\therefore I_R = 10 I_i = \frac{0 - V_x}{R}$

But $V_x = 0 - I_i(10k) = -(10k) I_i$

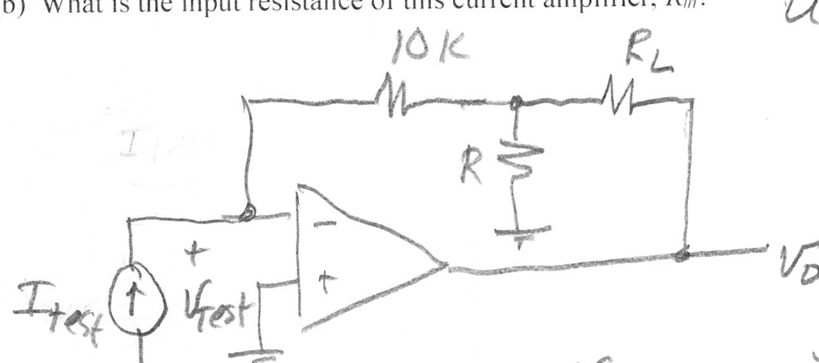
$\therefore 10 R I_i = -(-10k \cdot I_i) \Rightarrow 10R = 10K$

$\therefore \boxed{R = \frac{10K}{10} = 1K}$

R =	1 KΩ

(b) What is the input resistance of this current amplifier, R_{in}?

Use test source to find Rin:



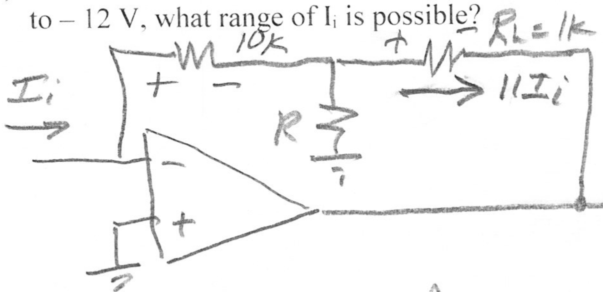
$R_{in} = \frac{V_{TEST}}{I_{TEST}} = \frac{0}{I_{TEST}} = 0$

IDEAL OPAMP with Negative Feedback means $V_{in}^- = V_{in}^+ = 0$

$\therefore V_{TEST} = 0$

R_{in} =	0 Ω

(c) If $R_L = 1\ k\Omega$ and the opamp operates in an ideal manner as long as V_o is in the range +12 V to – 12 V, what range of I_i is possible?



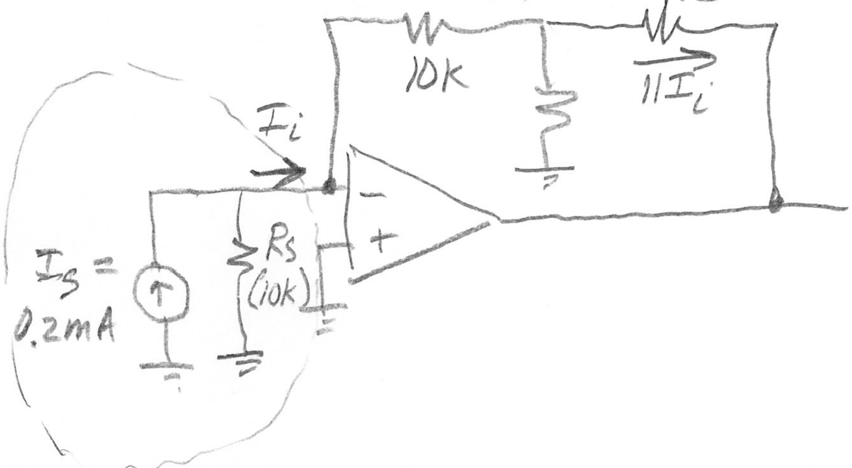
$$V_o = 0 - I_i\,(10k) - 11 I_i\,(1k)$$
$$= -10k\,I_i - 11k\,I_i$$
$$= -21k\,I_i$$

$$I_i\,(max) = -\frac{V_o\,(max)}{21K} = \frac{-12\,V}{21K} = -0.57\,mA$$

$$I_i\,(min) = -\frac{V_o\,(min)}{21K} = -\frac{(-12V)}{21K} = +0.57\,mA$$

I_i range	$-0.57\,mA \le I_i \le 0.57\,mA$

(d) If the amplifier is fed with a current source having a current of 0.2 mA and a source resistance of 10 kΩ, find I_L.



Norton equivalent input current source

Because of ideal opamp with negative feedback,

$V_{in}^{+} = V_{in}^{-} = 0\ V.$

$\therefore$ Current through R_S, $I_{R_S} = 0$

$\therefore I_i = I_S = 0.2\,mA$

$\therefore \boxed{I_L = 11\,I_i = 2.20\,mA}$

I_L=	2.20 mA