UNIVERSITY OF CALIFORNIA AT BERKELEY
College of Engineering
Department of Electrical Engineering and Computer Sciences
EE105 Lab Experiments

Experiment 6: Single-Stage Amplifiers
Pre-Lab Worksheet

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Lab group: Tuesday 8-11 / Tuesday 5-8 / Thursday 8-11 / Thursday 5-8

Before adding Cadence plots to your report, please **change the background color to white**:
Edit->Properties-> Click the black rectangle near the "Background" -> change to white.
Submit the pre-lab worksheet to Gradescope. It will be due before the start of lab.

2. Pre-Lab

2.1. Specifications

2.2. Biasing Circuit

2.2.1. What is the transfer function v_g / v_{in} ? You can assume that $R_{g2} >> 100\Omega$ to simplify your calculations.

$$\frac{v_g}{v_{in}} = 101 \frac{sR_{g1}R_{g2}C_{in}}{sR_{g1}R_{g2}C_{in} + \left(\frac{10^4}{101}\,\Omega\right)sC_{in}(R_{g1}+R_{g2}) + (R_{g1}+R_{g2})}$$

2.2.2. What kind of response is it (low-pass/band-pass/high-pass)? What its 3dB frequency?

This is a high-pass filter.

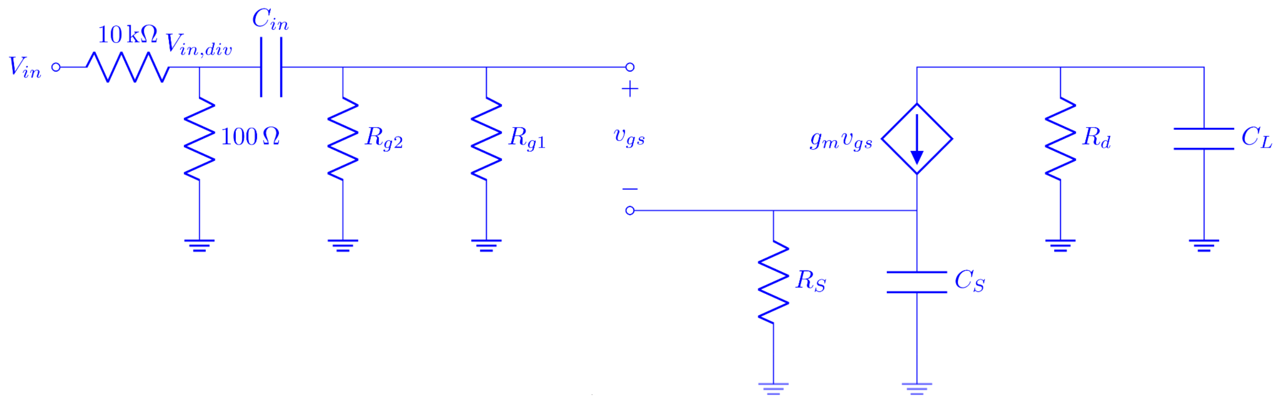
2.2.3. What is the problem with biasing the transistor with R_s=0? How does R_s solve this problem? Why do we need the C_s capacitor in the circuit?

Due to the temperature increasing the gain the the transistor which increases the temperature, this can create a snowball effect that can break down the transistor. The bias resistor prevents this by limiting the current through the source.

We need the capacitor in order to pull down any AC signals that could affect the operating point.

2.3. Transfer Function

2.3.1. Draw a small-signal equivalent circuit of the entire amplifier. Write an expression for the transfer function v_{out} / v_g .



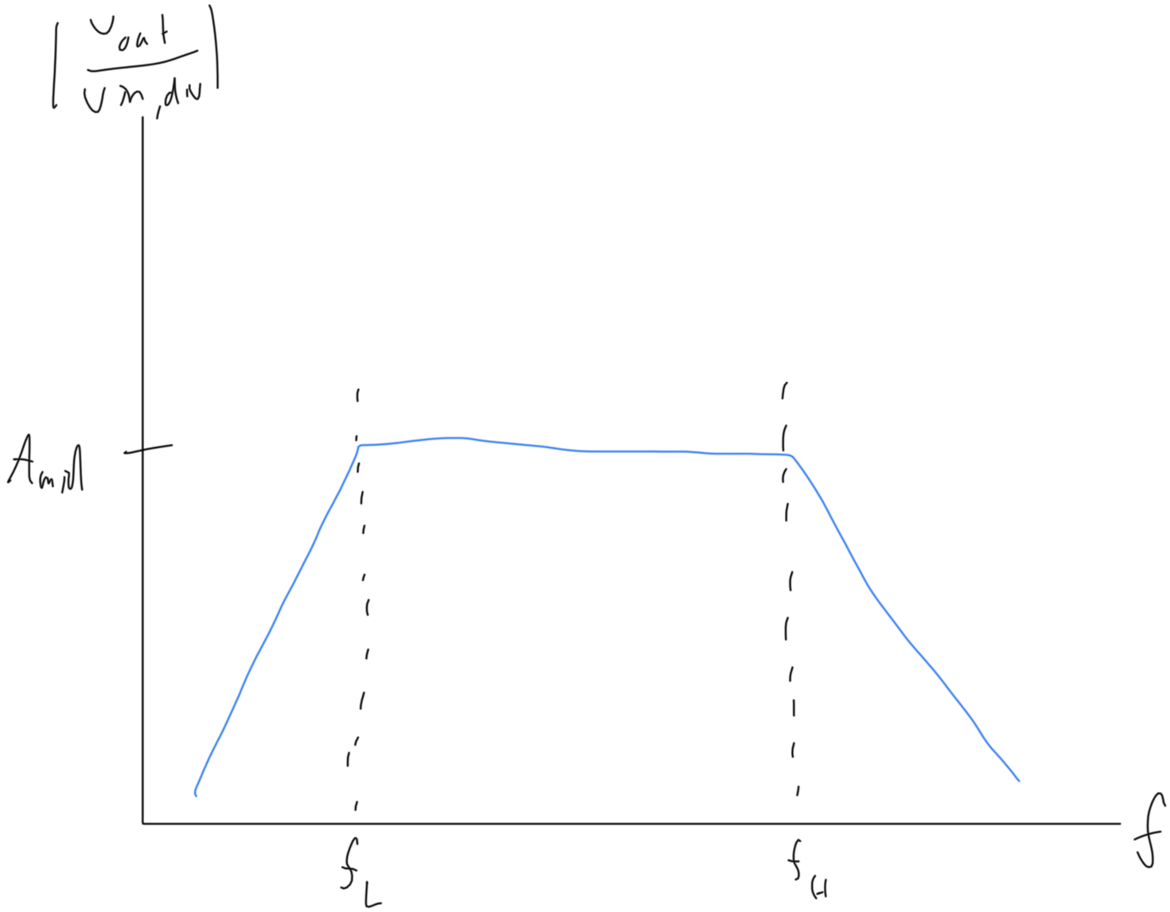
$$\frac{v_{out}}{v_g} = -\frac{g_m(R_d \parallel \frac{1}{sC_L})}{1 + g_m(R_s \parallel \frac{1}{sC_s})}$$

2.3.2. Now write an expression for the desired transfer function $A = \dfrac{v_{out}}{v_{in,div}}$. What are the poles and zeros of the transfer function? What is the mid-band gain A_{mid}? What is the high -3dB frequency f_H? Sketch a bode plot of the transfer function.

$$\frac{v_{out}}{v_{in,div}} = \frac{s(R_{g1} \parallel R_{g2})C_{in}}{1 + s(R_{g1} \parallel R_{g2})C_{in}} \left(-\frac{g_m R_d(1 + sR_sC_s)}{(1 + sR_dC_L)(1 + g_mR_s + sR_sC_s)} \right)$$

$$A_{mid} = \frac{g_m R_d}{1 + g_m R_s}$$

$$f_H = \frac{1}{2\pi R_d C_L}$$



2.3.3.Calculate the required values of the resistors and capacitors to meet the specifications.

$$R_d = \frac{1}{2\pi f_H C_L}$$

$$g_m = \frac{A_{mid}}{R_d}$$

$$R_s = \frac{2V_s}{g_m V_{ov}}$$

$$R_{g2} = \frac{R_{g1}}{\frac{V_{DD}}{V_g} - 1}$$

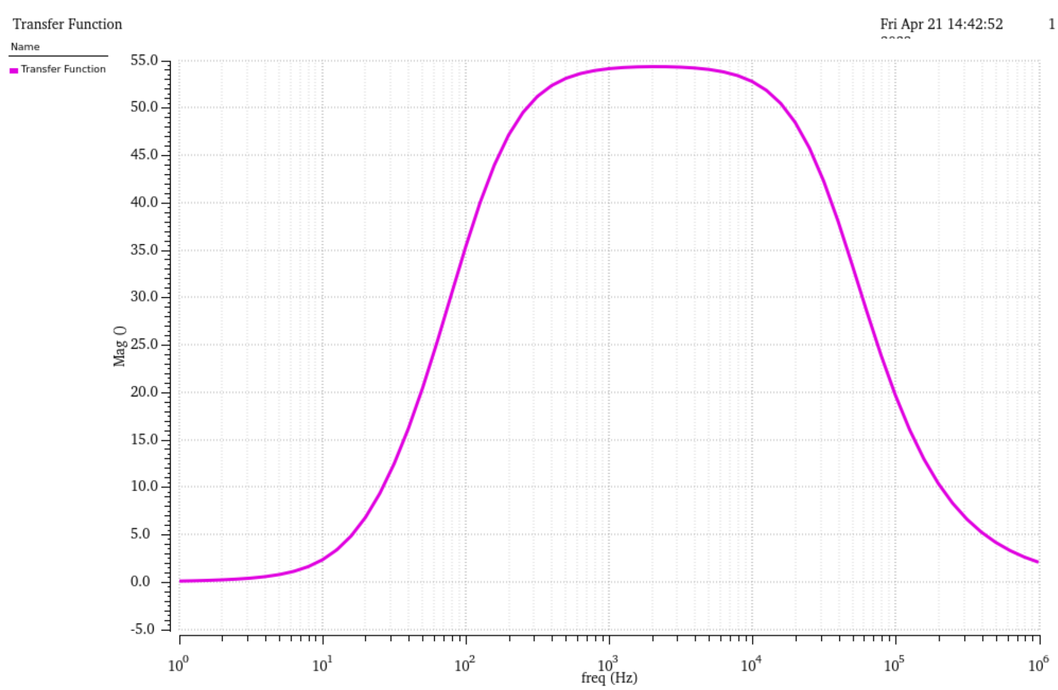
$$C_{in} = \frac{1}{2\pi f_L (R_{g1} \parallel R_{g2})}$$

R_D = 7.9 kΩ
g_m = 6.3 mS
R_S = 1.6 kΩ
R_{g2} = 2.71 kΩ
C_{in} = 3.7 μF
C_s = 20 μF (by design)

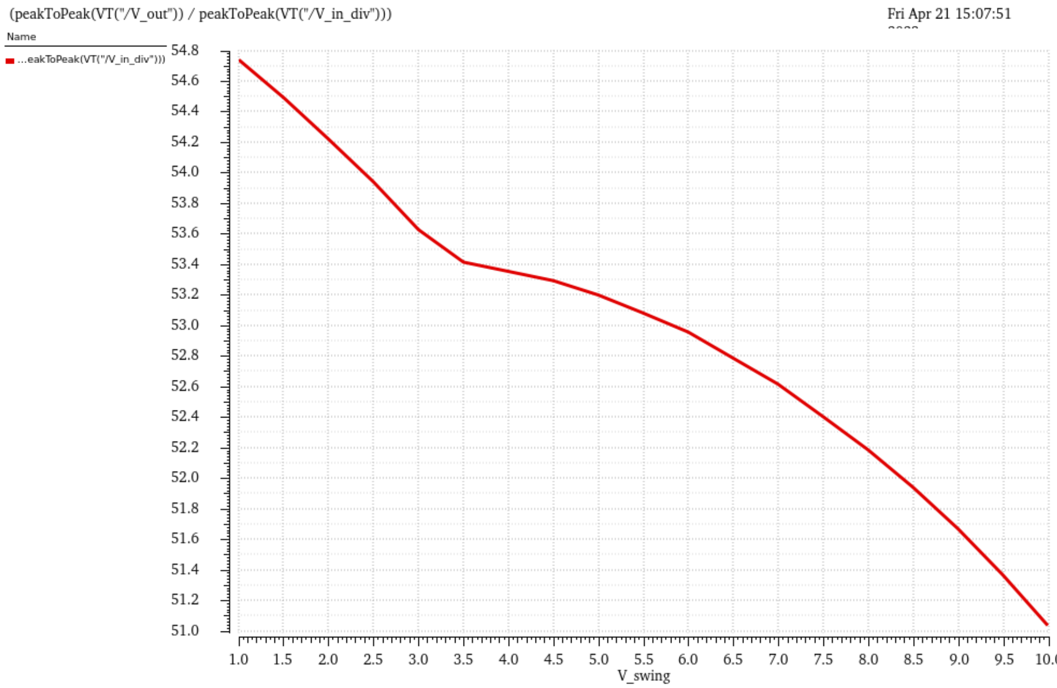
2.3.4. Change the component values in the simulation if needed to meet specifications and list those values.

Component	Hand calculation	Cadence simulation
R_d	7.9 kΩ	4 kΩ
R_s	1.6 kΩ	1.6 kΩ
C_s	20 μF	20 μF

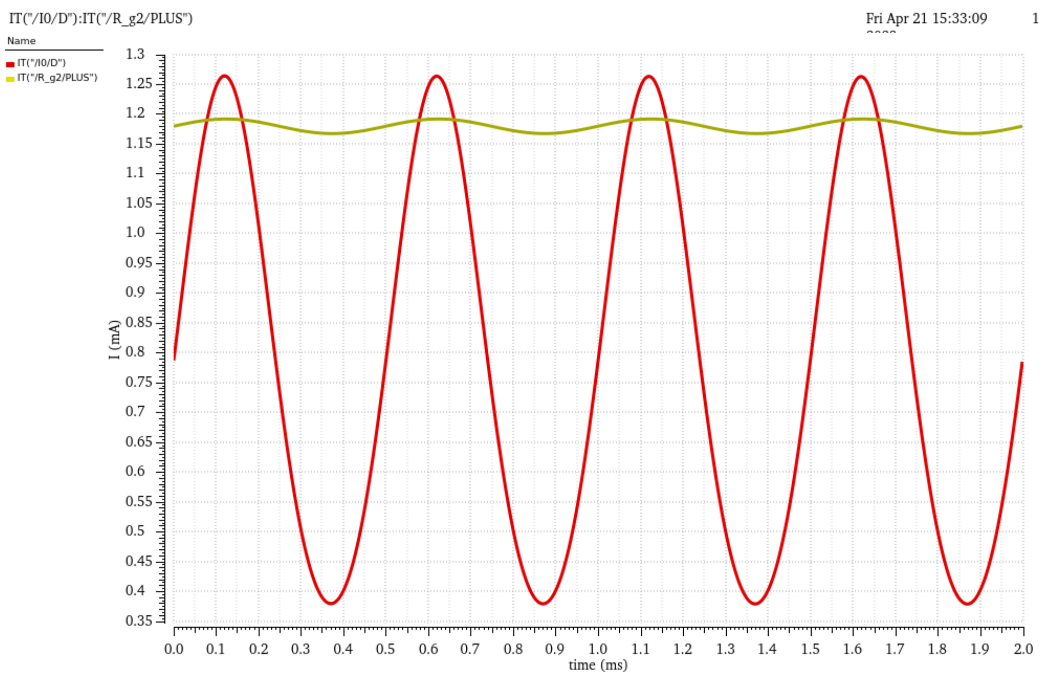
2.3.4.1. Use AC analysis to plot the transfer function.



2.3.4.2. Use transient analysis to verify the output swing requirement.



2.3.5. What is the simulated total current consumption of the amplifier? What part of it is the transistor and what part is the R_{g1},R_{g2} biasing?



The peak current consumption of the amplifier is 2.3 mA, split mostly half-and-half between the transistor and the resistor biasing.

2.3.6. Fill out the following table with all of the values you got from hand calculation and cadence simulation:

Parameter	Spec	Hand calculation	Cadence simulation	Units

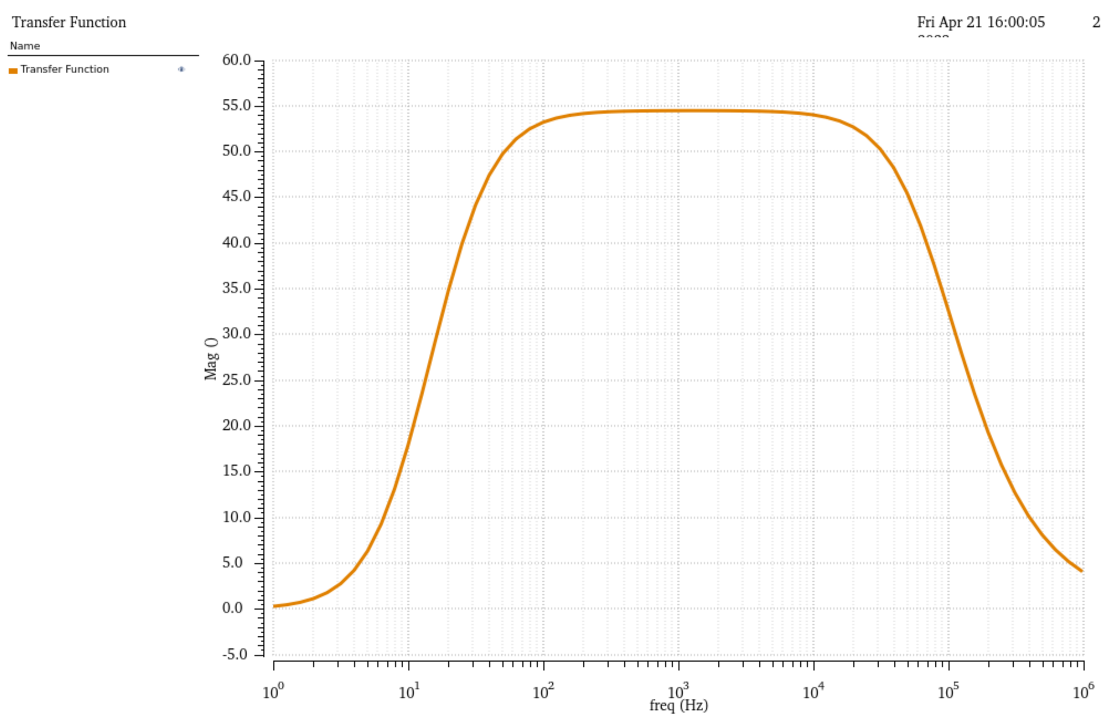
Middle band gain (A_{mid})	>50	50	55	-
High -3dB frequency (f_H)	>20	20	20	KHz
Low -3dB frequency (f_L)	<300	-	250	Hz
Output Swing	>6	-	3.5	Vptp

2.4. Higher bandwidth spec

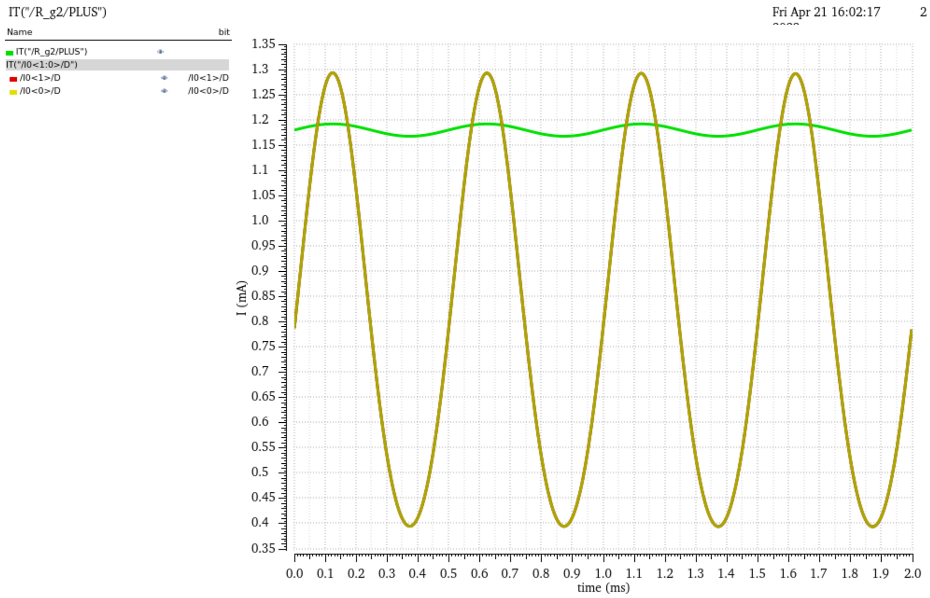
2.4.1. What should be the new values of Rd, Rs and Cs to fulfill the new spec? *Hint*: do not repeat the calculations from part 2.3. Think about the difference from the previous circuit.

Component	**Hand calculation**	**Cadence simulation**
R_d	3.95 kΩ	2 kΩ
R_s	800 Ω	800 Ω
C_s	40 µF	500 µF

2.4.2. Attach the AC transfer function plot of the new design.



2.4.3. What is the simulated total current consumption of the amplifier? What part of it is the transistor and what part is the R_{g1},R_{g2} biasing?



The peak current consumption of the amplifier is 3.5 mA, split as a 2:2:1 ratio between the transistors and the resistor biasing.

2.4.4. Fill out the following table with all of the values you got from hand calculation and cadence simulation:

Parameter	Spec	Hand calculation	Cadence simulation	Units
Middle band gain (A_{mid})	>50	50	55	-
High -3dB frequency (f_H)	>20	20	25	KHz
Low -3dB frequency (f_L)	<300	-	100	Hz
Output Swing	>6	-	3	Vptp