UNIVERSITY OF CALIFORNIA, BERKELEY
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE 105: Microelectronic Devices and Circuits

Fall 2017 Prof. Ming Wu

MIDTERM EXAMINATION #1
Time allotted: 80 minutes

NAME: ______________________ ______________________ ______________________
(print) Last First Signature

STUDENT ID#: ____________________

INSTRUCTIONS:

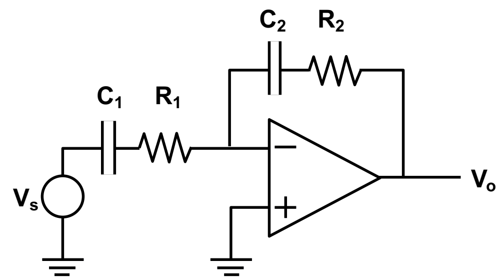
1. **SHOW YOUR WORK. (Make your methods clear to the grader!)**
2. **Clearly mark (underline or box) your answers.**
3. **Specify the units of your answer to receive full credit.**
4. **Unless stated in the problem, use the values of physical constants provided below.**
5. **You can use approximations within 20% accuracy any time.**
6. **Calculator is allowed. (Cell phone is not allowed).**

****** If you need more space for your answer, use the blank pages in the back. Clearly label which problem is your answer for ******

Commonly used constants and physical parameters:		
Electronic charge	q	1.6×10^{-19} C
Boltzmann's constant	k	8.62×10^{-5} eV/K
Thermal voltage at 300K	$V_T = kT/q$	0.025 V
Relative permittivity of Si	$\epsilon_{r,Si}$	12
Relative permittivity of SiO_2	$\epsilon_{r,ox}$	4
Vacuum permittivity	ϵ_0	$8.854\text{x}10^{-14}$ F/cm

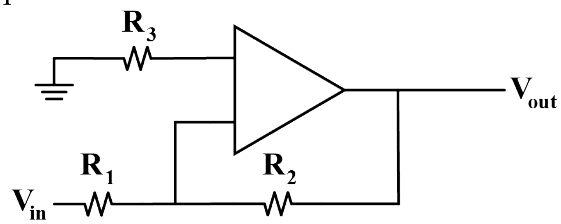
Points	Problem 1	20	
	Problem 2	30	
	Problem 3	20	
	Problem 4	30	
	Total	100	

1) A simple filter is shown below: (OpAmp is ideal)



a) What is the transfer function $H(j\omega) = V_o/V_s$?
b) What is the expression of low frequency gain in dB?
c) What is the 3-dB frequency (in Hz) of the filter?
d) Assume $C_1 = 100\ pF, C_2 = 10\ pF, R_1 = 10\ k\Omega, R_2 = 1\ k\Omega$, draw the magnitude Bode plot. Clearly label the graph, including all the breakpoints (in magnitude and frequency).
e) Draw the phase Bode plot using the same numerical values. Clearly label the graph.

2) Consider the *stable* amplifier circuit below:

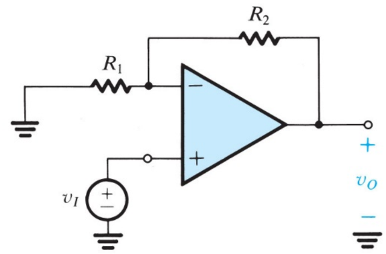


a) Label the plus and minus terminals in the schematic above.
b) Calculate the transfer function, assuming the op-amp is ideal.

Now, assume that the op-amp has a finite open-loop gain, A_0, and a pole at frequency ω_0.

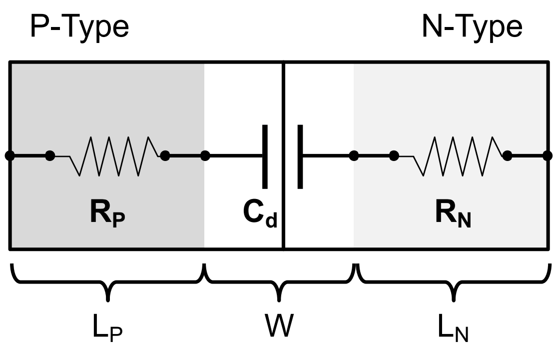
c) Write out the transfer function representing the op-amp's behavior in open-loop.
d) Using this non-ideal op-amp, calculate the transfer function V_{out} / V_{in}.
e) What are the locations of the poles and zeros?
f) Assume the op-amp has the following metrics: A_0 = 100dB, f_0 = 50kHz. Can you make closed loop amplifiers with the following metrics?
   i) Closed-loop Gain of 50, bandwidth of 100GHz.
   ii) Closed-loop Gain of 1, bandwidth of 5GHz
   iii) Closed-loop Gain of 0.1, bandwidth of 40GHz.

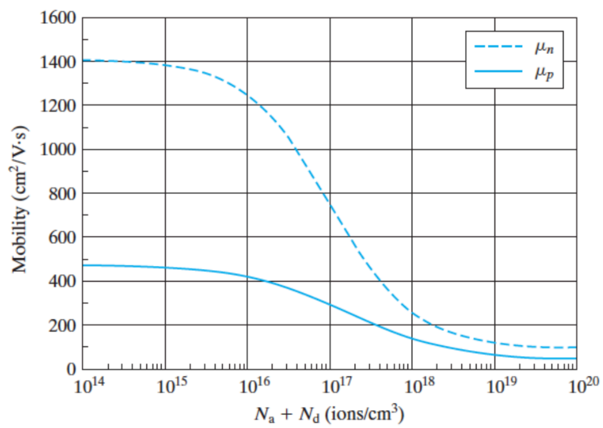
3) A non-inverting amplifier with variable gain is shown on the right. Here, $R_1 = 1\ k\Omega$ and R_2 is variable from $1\ k\Omega$ to $1\ M\Omega$. This input signal is a sinusoidal signal with an amplitude of 100 mV and a frequency of $\omega = 10^6$ rad/s. The Op Amp has a slew rate (SR) of 1 V/µs.



   a) First, assume the Op Amp has infinite bandwidth. If we gradually increase the gain of the amplifier by increasing R_2, at what value of R_2 does the output become slew rate limited?
   b) Now consider the Op Amp with a finite gain-bandwidth product of 100 MHz and $R_2 = 49\ k\Omega$. The input signal amplitude is fixed at 1 mV, but the frequency is gradually increasing from 100 Hz to higher frequency. Do we encounter bandwidth limit or slew rate limit first? What is that frequency?

4) Consider a p-n junction with N-type doping of $N_D = 10^{18}$ cm^{-3} and P-type doping of $N_A = 10^{16}$ cm^{-3}. The length of the N- and P-doped regions are $L_N = L_P = 10\ \mu m$. The cross-sectional area is $A = 10\ \mu m^2$. Assume the intrinsic carrier concentration is $n_i = 10^{10}$ cm^{-3}.
   a) What is the built-in voltage of the p-n junction?
   b) Is the depletion region mostly in the P-side or the N-side?
   c) What is the depletion capacitance at zero bias?
   d) This capacitance is bias dependent. At what voltage will the capacitance reduce to ½ of the zero-bias value? Specify the polarity of the bias (i.e., forward or reverse).
   e) The small-signal equivalent circuit of a p-n junction is shown below. The P and N doped region forms a series resistance. Using the mobility chart below, find the series resistance at P and N region.





   f) The small signal equivalent circuit of the p-n junction diode at reverse bias is shown below. What is the bandwidth of this device at zero bias? (*Hint: Bandwidth is defined as the 3-dB cut-off frequency of* $G(j\omega) = i_S/v_S$.)