EE 330
Homework 6
Spring 2024 (This assignment is due Friday February 23 at noon)

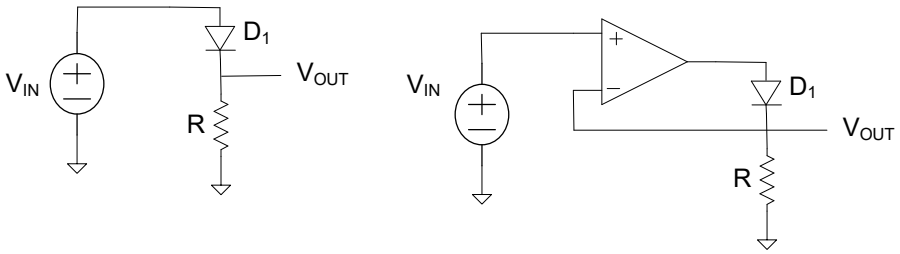
Assume a CMOS process is characterized by model parameters extracted from a 0.18µm process described in the table appended below.

Problem 1 Assume a resistor has a resistance of 1KΩ at T=300°K. If the TCR of this resistor is constant of value 2000 ppm/°C, what will be the resistance at T=350°K?

Problem 2 Consider an n+ diffused resistor that is 200u long, 1.5u wide, and 2u thick. What is the nominal value of the resistance if it is doped with Phosphorus and the doping density is uniform 5E14/cm^3.

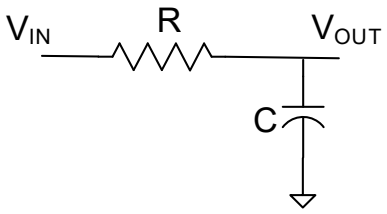
Problem 3 Consider the two circuits shown below. Assume R=1KΩ and that the op amp is ideal. Assume the diode can be modeled by a piecewise linear model with a cut-in voltage of 0.6V.

a) Derive an expression for and plot the transfer characteristics (V_{OUT} vs V_{IN}) for both circuits and comment on the relative performance of the two circuits
b) From the results obtained in Part a), plot the output of both circuits if V_{IN}=10sin(1000t)
c) Repeat part b) if V_{IN}=sin(1000t)
d) Repeat part b) if V_{IN}=0.25sin(1000t)



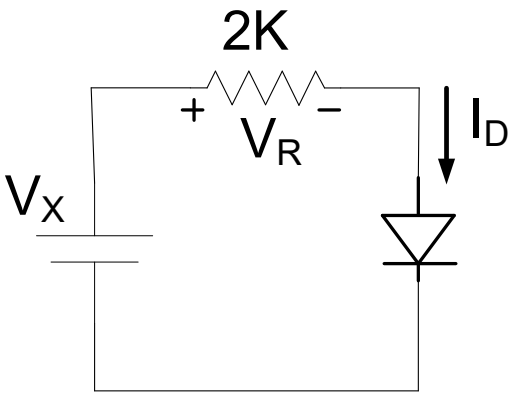
Problem 4 Consider the first-order lowpass filter (LPF) shown below that has a 3dB frequency of 10MHz when operating at T=273°K. Assume the resistor has a value of 10KΩ at this operating temperature.

a) If the TCR of this resistor is constant of value 2300 ppm/°C and the capacitor has a constant TCC of 1000 ppm/°C, plot the frequency response for the LPF at T=273°K and T=350°K.
b) What percent change occurs in the 3dB frequency when the temperature is increased from T=273°K to T=350°K. Assume the temperature coefficients used in part a)



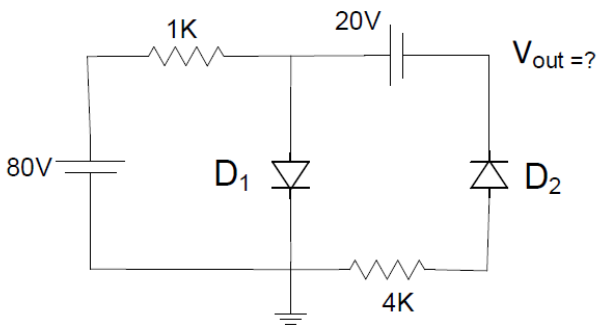
Problem 5 If the voltage of a forward-biased pn junction is varied between 0.5V and 0.6V, what is the range in the diode current. Assume the junction area of the diode is $50\mu^2$ and $J_S=10^{-15}A/\mu^2$.

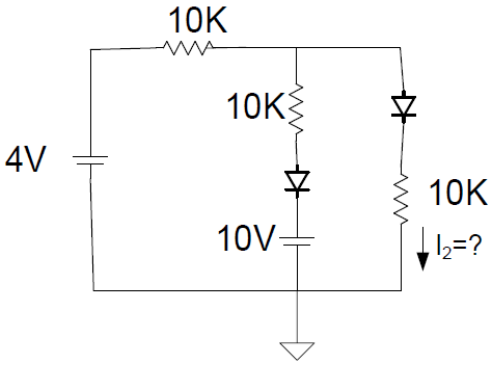
Problem 6 Determine the current I_D (within ±5%) if $V_X=10V$ for the following circuit. Assume the area of the diode is $200\mu^2$ and $J_S=10^{-15}A/u^2$.



Problem 7 Repeat Problem 6 if $V_X=520mV$.

Problem 8 Determine the quantities indicated with a ? in the following circuits. Assume the diodes are ideal.

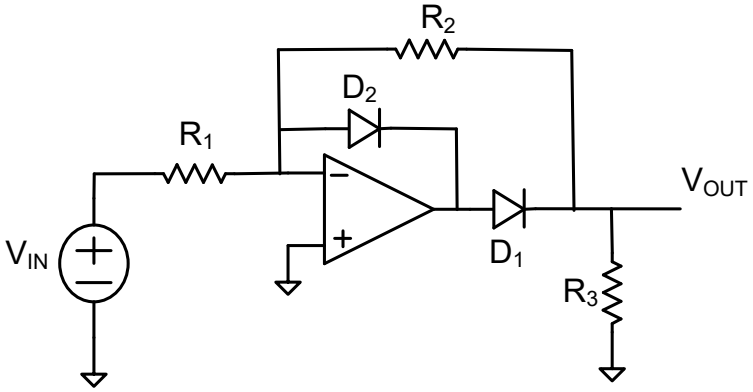




Problem 9 Assume the op amps and the diodes are ideal in the following circuit.

a) Obtain an expression for and plot V_{OUT} vs V_{IN} for this circuit

b) Comment on what useful function this circuit performs



Problem 10 Implement a 4 to 1 multiplexer and a 1 to 4 demultiplexer, both with an active low enable pin, using Verilog. When the multiplexer/demultiplexer is disabled, its output should be low. Design a testbench proving function using Verilog. Submit module code, testbench code, and Modelsim waveforms.

Passive Process Parameters for 0.18 µm CMOS Process								
	N+	P+	POLY	M1	M2	M3	N_W	UNITS
RESISTANCES								
Sheet Resistance	6.6	7.5	7.7	0.08	0.08	0.08	941	Ohms/sq
Contact Resistance	10.1	10.6	9.3		4.18	8.97		Ohms
CAPACITANCES								
Area (substrate)	998	1132	103	39	19	13	127	af/µm^2
Area (N+ active)			8566	54	21	14		af/µm^2
Area (P+active)			8324					af/µm^2
Area (POLY)				64	18	10		af/µm^2
Area (metal 1)					44	16		af/µm^2
Area (metal 2)						38		af/µm^2
Fringe (substrate)	244	201		18	61	55		af/µm
Fringe (poly)				69	39	29		af/µm
Fringe (metal 1)					64	35		af/µm
Fringe (metal 2)						54		af/µm
Overlap (P+active)			652					af/µm

Passive Process Parameters for ON 0.5µm CMOS Process											
	N+	P+	POLY	POLY2	HR_P2	M1	M2	M3	N/PLY	N_W	UNITS
RESISTANCES											
Sheet Resistance	84	105	23.5	999	44	0.09	0.10	0.05	825	815	Ohms/sq
Contact Resistance	65	150	17		29		0.97	0.79			Ohms
CAPACITANCES											
Area (substrate)	425	731	84			27	12	7		37	af/µm^2
Area (N+ active)			2434			35	16	11			af/µm^2
Area (P+active)			2335								af/µm^2
Area (POLY)				938		56	15	9			af/µm^2
Area (POLY2)						49					af/µm^2
Area (metal 1)							31	13			af/µm^2
Area (metal 2)								35			af/µm^2
Fringe (substrate)	344	238				49	33	23			af/µm
Fringe (poly)						59	38	28			af/µm
Fringe (metal 1)							51	34			af/µm
Fringe (metal 2)								52			af/µm
Overlap (N+active)			232								af/µm
Overlap (P+active)			312								af/µm