National Exams

98-Comp-A1, Electronics

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to indicate, with the answer, a clear statement of any assumptions made.

2. This is a OPEN BOOK exam.
   Any non-communicating calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper.
   The first 5 questions as they appear in the answer book will be marked.

4. Each question is of equal value.

Question 1 (20 marks)

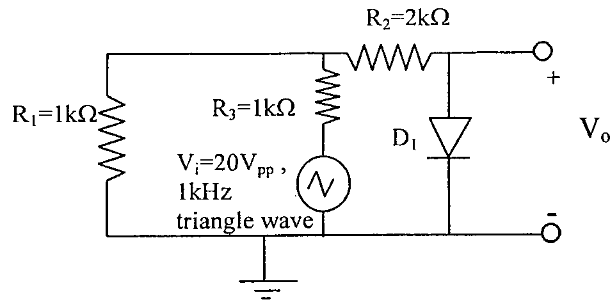

Figure 1. The diode can be replaced by piece-wise linear model with V_D=0.7V, R_S=10Ω for forward bias.

For the circuit shown in Figure 1:

a) Sketch V_i and V_o as a function of time, indicating peak voltages.

b) What is the peak reverse voltage across D_1?

c) What is the peak power dissipated in D_1?

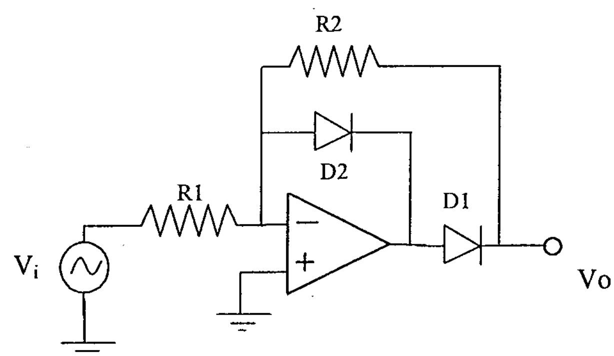

Figure 2. Assume the diodes have a voltage drop V_D=0.7V when conducting. R1=R2=1kΩ.

For the circuit shown in Figure 2:

d)) For V_i=10V sin(2π60t) sketch the output $V_o(t)$. Label key voltages and times, and indicate changes in operating region for each diode.

Question 2 (20 marks)

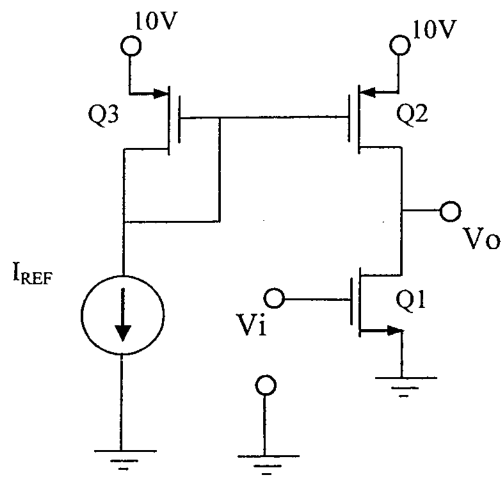

Figure 3. $k_n' = \mu_n C_{ox} = 1\ mA/V^2$, $k_p' = 40\ \mu A/V^2$, $W/L = 10\ \mu m$, $V_{tn} = -V_{tp} = 1V$, $|V_A| = 100V$

For the circuit shown in Figure 3:

a) Draw a small signal ac equivalent circuit.

b) Find an expression for voltage gain V_o/V_i.

c) Choose a bias current I_{REF} to provide a gain of 200 V/V.

d) A load resistor of 100 kΩ is connected from V_o to ground. What is the voltage gain?

Question 3 (20 marks)

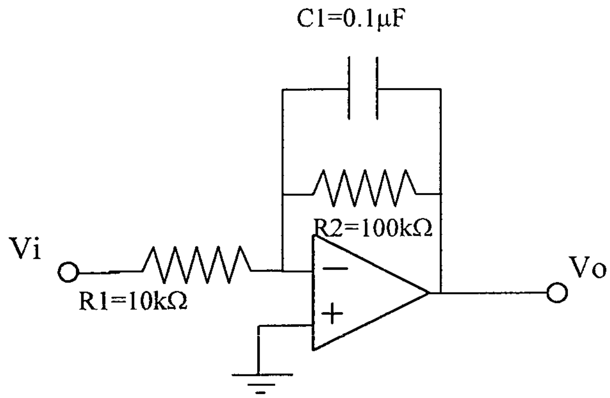

Figure 4.

For the circuit shown in Figure 4:

a) Derive the transfer function $\frac{Vo(j\omega)}{Vi(j\omega)}$ for the circuit shown, assuming the op-amp is ideal.

b) Find the DC gain, 3dB frequency, and the unity gain bandwidth for this circuit.

c) If Vi(t)=1sin(200t) V, find Vo(t).

d) If the op-amp has a finite gain A=10^4 V/V, find the transfer function $\frac{Vo(j\omega)}{Vi(j\omega)}$.

Question 4(20 marks)

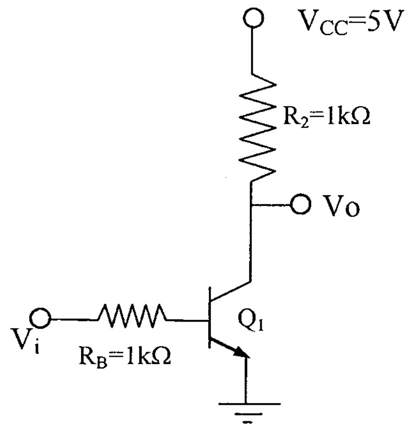

Figure 5. V_{be}=0.7V (active), V_{ce}=0.2V (saturation), β=100.

For the circuit shown in Figure 5:

a) What value of V_i will make Q_1 active? What is the expression for Vo for this input?

b) What value of V_i will make Q_1 saturate?

c) For Q_1 active with I_C=1mA, draw the small signal AC equivalent circuit. Evaluate the voltage gain.

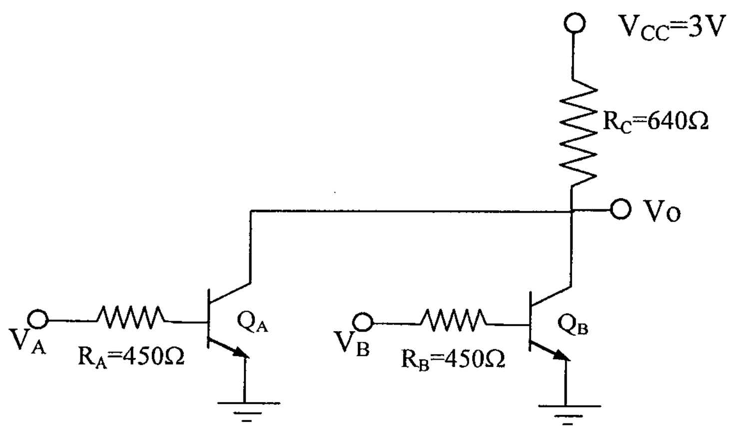

Figure 6. V_{be}=0.7V (active), V_{ce}=0.2V (saturation), β=100.

d) For V_A=V_B=0V, what is the state of each transistor and the value of Vo?

e) For V_A or V_B=3V, what is the state of each transistor and the value of Vo?

Question 5 (20 marks)

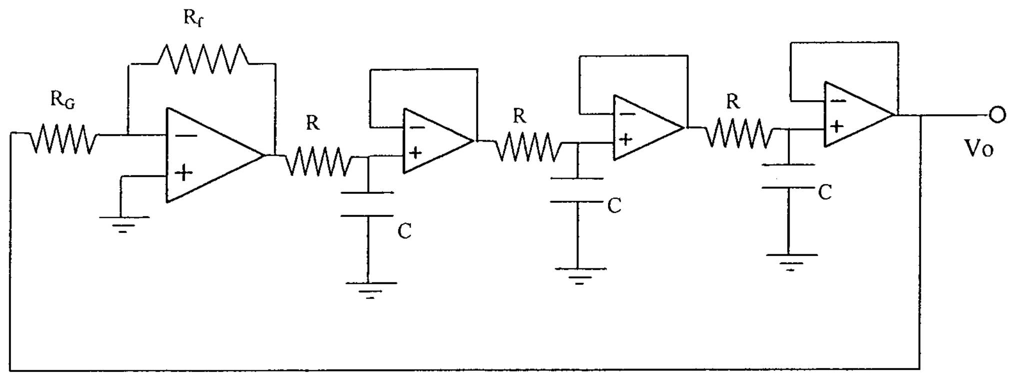

Figure 7. Assume the op-amps are ideal. R=10kΩ, R_f=100 kΩ

For the circuit shown in Figure 7:

a) Find the loop gain expression.

b) What condition on the loop gain will result in oscillation? What is the expression for oscillation frequency for this circuit?

c) Choose a value R_G that will initiate oscillation.

d) Choose a value C to provide an oscillation frequency of 1kHz.

Question 6 (20 marks)

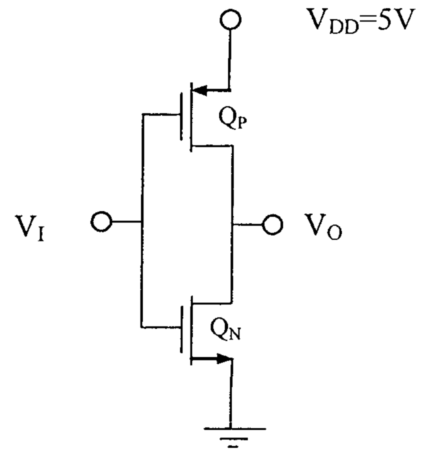

Figure 8. k_n'=50 $\mu A/V^2$, k_p'=20 $\mu A/V^2$, V_{tn}=-V_{tp}=1V, C_{ox}=1fF/μm^2

a) If the minimum gate length for this technology is 1 μm, size Q_N and Q_P to obtain a symmetric transfer characteristic.

b) Estimate the propagation delay if the inverter drives a second identical inverter. Consider only the gate oxide contribution to capacitance.

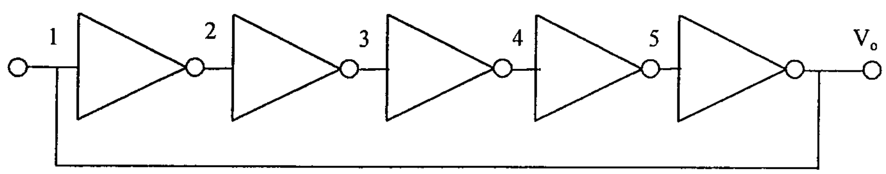

Figure 9.

For the circuit shown in Figure 9:

c) For a low to high transition at node 1 at t=0s, sketch the waveforms at all 5 nodes for one full period.

d) If the propagation delay for a single inverter is 0.5 ns, what is the frequency of the signal supplied by this circuit?

Question 7 (20 marks)

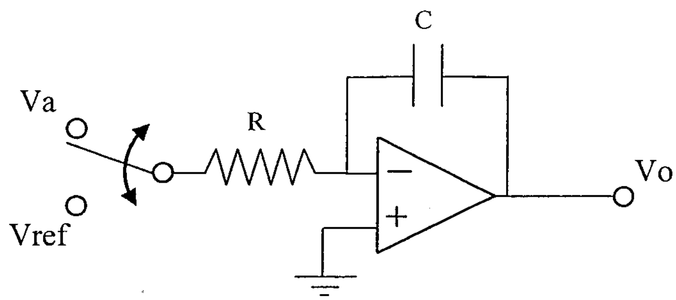

Figure 10.

a) Initial value of V_o=0V. At t=0s the switch is connected to V_a (negative). What is $V_o(t)$?
b) At $t=T_1$ S is moved to connect to V_{ref} (positive). How long (T_2) will it take for V_o to return to 0V?
c) A counter measures T_1 and T_2. If the counter value is n_{ref} at $t=T_1$, what is the value at $t=T_2$?
d) If V_{ref}=10V and $n_{ref}=2^8$, what is the voltage resolution in measuring V_a?

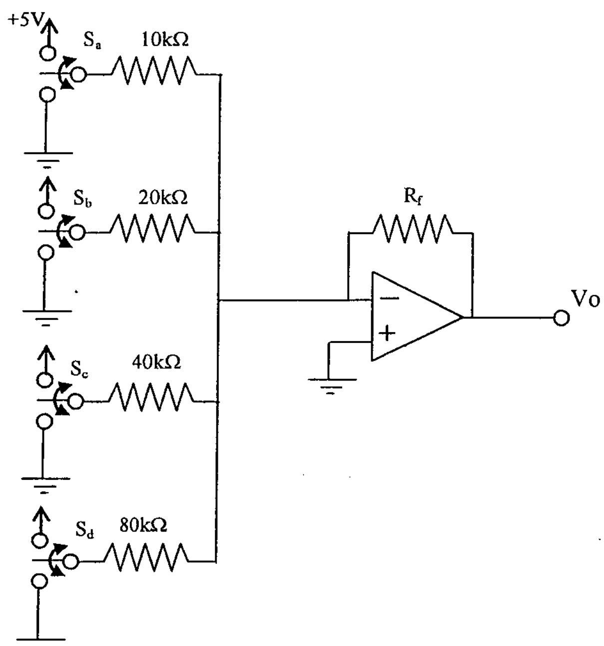

Figure 11.

e) For the circuit in Figure 11, find the expression for V_o as a function of switch positions S_a to S_d. Which switch represents the most significant bit?

Marking Scheme

1. 20 marks total (4 parts, 5 marks each)
2. 20 marks total (4 parts, 5 marks each)
3. 20 marks total (4 parts, 5 marks each)
4. 20 marks total (a),b),c) 5 marks each, d) 2 marks, e) 3 marks)
5. 20 marks total (4 parts, 5 marks each)
6. 20 marks total (4 parts, 5 marks each)
7. 20 marks total (a) 4 marks, b) 4 marks, c) 3 marks, d) 4 marks, e) 5 marks)