National Exams  December 2008

98-Comp-AI, 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.
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Question 1 (20 marks)

![Circuit Diagram](image)

Figure 1. Assume the diodes can be replaced by piece-wise linear models with \( V_D = 0.7 \text{V}, \)
\( R_S = 10 \Omega \) for forward biased diodes, and \( V_Z = 5 \text{V}, R_Z = 10 \Omega \) for Zener operation.

For the circuit shown in Figure 1:

a) Sketch \( V_t \) and \( V_o \) as a function of time, indicating peak voltages.

b) What are the peak forward and reverse currents through \( D_1 \)?

c) What power rating would you specify for the diode?

![Circuit Diagram](image)

Figure 2. Assume the diodes have a voltage drop \( V_D = 0.7 \text{V} \) when conducting. The circuit is in steady state and \( C_1 = C_2 \).

For the circuit shown in Figure 2:

d) Sketch \( V_A \) as a function of time.

e) Sketch \( V_o \) as a function of time.

f) Determine the peak inverse voltage across each diode.
Question 2 (20 marks)

Figure 3. \( K_n = 50 \, \mu A/V^2 \), \( K_p = 20 \, \mu A/V^2 \), \( V_{in} = V_{ip} = 1 \, V \)

For the circuit shown in Figure 3:

a) Calculate the dc bias point, indicating \( V_{DS} \), \( V_{GS} \) and \( I_D \) for the transistor.

b) Draw a small signal ac equivalent circuit.

c) Find the voltage gain \( V_o/V_i \).

d) Find the input resistance \( R_i \), as indicated in the Figure.
Question 3 (20 marks)

Figure 4. Assume the op-amp is ideal.

For the circuit shown in Figure 4:

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

b) Calculate the input impedance of the circuit shown. What is the purpose of \( R_i \)?

c) Sketch a Bode plot of the magnitude of the transfer function, showing all the important features.

d) Sketch a Bode plot of the phase of the transfer function, showing all the important features.
Question 4 (20 marks)

Figure 5. Neglect the transistor capacitances.

For the circuit shown in Figure 5:

a) Sketch the small signal ac equivalent circuit (using $r_e$ and $\beta$ to model the transistor).

b) Write ac node equations for the equivalent circuit.

c) Find an expression for the frequency of oscillation.

d) Choose values $R_E$, $C_1$ and $C_2$ for a 5MHz oscillator if the transistor has a minimum $\beta=50$ and $I_C=1mA$. 
Question 5 (20 marks)

Figure 6. Assume the op-amp is ideal and can provide ±15 V output.

For the circuit shown in Figure 6:

a) Evaluate $V_C(t)$.

b) Show the switching frequency is $f = 1/(2R_3 \ln(3))$.

c) Choose values for $R_3$ and $C$ to implement a 10kHz oscillator, if the amplifier input bias current is 0.5 μA.
**Question 6 (20 marks)**

Figure 5. $K_n=50 \mu A/V^2$, $K_p=20 \mu A/V^2$ $V_{in}=-V_{qp}=1V$

a) Draw a truth table for the circuit in Figure 5, indicating the state (off/on) of the transistors, and write the Boolean expression for $V_o$.

b) For an inverter with a symmetrical transfer characteristic and a 2$\mu$m channel length, the ratio (W/L) for N-channel transistors is 2, and for p-channel transistors is 5. If the same 2$\mu$m technology is used for the circuit in Figure 5, find the appropriate W/L ratios for the transistors.

Figure 6. $\beta$ is very large, $V_{BE}=0.7V$

For the circuit shown in Figure 6:

- c) Find $V_Y$ if $V_A=V_B=-2 V$.

- d) Find $V_Y$ if $V_A=0V$ and $V_B=-2 V$. What logic function does this circuit implement?
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**Question 7 (20 marks)**

An analog signal between 0V and +10V must be converted to an 8 bit digital signal.

a) What is the resolution of the converter in volts?

b) If the input signal is 4V, what is the digital signal value?

c) What is the error in quantization of an input signal of 4.1V?

d) If a flash converter is selected as the conversion circuit, sketch the circuit and provide a brief description of its operation. What is the advantage of this circuit over other conversion circuits?

e) If a dual-slope converter is selected, sketch the circuit and provide a brief description of its operation. What is the advantage of this circuit over other conversion circuits?

**Marking Scheme**

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