National Exams May 2015

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)

- \( V_1 = 10 \sin(2\pi t) \)
- \( R = 50 \Omega \)
- \( V_1 = 3V \)
- \( V_2 = 4V \)
- \( \text{Figure 1. The diodes have a voltage drop } V_D = 0.7V \text{ in forward bias.} \)

For the circuit shown in Figure 1:

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

b) How should \( D_1 \) be rated for power consumption?

c) What is the peak current in \( R_1 \)?

- \( V_1 = 10 \sin(2\pi t) \)
- \( C_1 \)
- \( D_1 \)
- \( D_2 \)
- \( R_i \)
- \( V_o \)
- \( \text{Figure 2. The diodes have a voltage drop } V_D = 0.7V \text{ in forward bias.} \)

For the circuit shown in Figure 2:

d) Sketch the output waveform \( V_o(t) \) in steady state. Label key voltages and times, and indicate changes in operating region for the diodes.
Question 2 (20 marks)

Figure 3. \( k_n' = \mu_n C_{ox} = 1 \text{ mA/V}^2 \), W/L=10, \( V_m = 1 \text{ V} \), \( |V_A| = 100 \text{ V} \)

For the circuit shown in Figure 3:

a) For \( V_i = 2 \text{ V} \) what is the current through Q3?

b) What is \( V_{DS} \) for Q1?

c) Draw a small signal equivalent model for the circuit.

d) What is the small signal AC gain of the circuit?
Question 3 (20 marks)

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 in Figure 4, assuming the op-amp is ideal.

b) Sketch the frequency response, indicating the 3dB frequency for this circuit.

c) If $V_i(t) = 10\sin(120\pi t)$ V, find $V_o(j\omega)$.

d) If $V_i(t) = 10\sin(120\pi t)$ V, find $V_o(t)$. 

Figure 4.
Question 4 (20 marks)

For the circuit shown in Figure 5:

a) If $V_i=0V$ DC, find the DC bias point for Q1?

b) Draw the small signal equivalent circuit and evaluate the small signal AC voltage gain.

c) Sketch $I_c$ vs $V_{ce}$ and show the operating point for the transistor.

d) How would you change the bias to obtain maximum signal swing?
Question 5 (20 marks)

Figure 6. Assume the gates are ideal and switch at $V_{DD}/2$.

For the circuit shown in Figure 6:

a) Explain the operation of this circuit.

b) Sketch the waveforms $V_c(t)$ and $V_{out}(t)$.

c) Find an expression for $V_c(t)$.

d) Find the period of the waveform if $R_1 = 10 \, k\Omega$ and $C_1 = 10 \, nF$. 

**Question 6 (20 marks)**

Figure 7. $k_n'=50 \mu A/V^2$, $k_p'=20 \mu A/V^2$, $V_{in}=-V_{tp}=1V$, $C_{ox}=1fF/\mu m^2$, $V_{DD}=5V$.

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

b) Estimate the maximum capacitance this circuit can drive with a propagation delay of less than 200 ps.

For the circuit shown in Figure 8:

c) Determine outputs X and Y for all possible inputs A and B. $\phi$ is a clock signal.

d) If $Q_1$ and $Q_2$ are sized as in part a), find a minimum size for $Q_5$ and $Q_6$ that will ensure $X$ can be pulled down to $V_{DD}/2$ or lower.
Question 7 (20 marks)

![Diagram of an ADC circuit](image)

Figure 9.

a) What is a common name for the ADC circuit shown in Figure 9? What is a principal advantage of this circuit over other ADC implementations?

b) What are the analog voltages at each of the comparator negative inputs? If $V_{in}=3V$ what are the logic values for $V_1$ through $V_4$?

c) List all possible combinations of $V_1$-$V_4$ and the corresponding binary output.

d) In an integrated circuit, how could $V_{ref}$ be generated?
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 (4 parts, 5 marks each)
5. 20 marks total (4 parts, 5 marks each)
6. 20 marks total (4 parts, 5 marks each)
7. 20 marks total (4 parts, 5 marks each)