National Exams December 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)**

![Circuit Diagram](image)

Figure 1. The diode has a voltage drop $V_D=0.7V$ 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) Find the maximum and minimum output voltage $V_o$.

c) What is the peak current through $R_i$?

![Circuit Diagram](image)

Figure 2. The diode has a voltage drop $V_D=0.7V$ in forward bias.

For the circuit shown in Figure 2:

d) Sketch the output waveform $V_o(t)$ in steady state. Label peak voltages.
Question 2 (20 marks)

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

For the circuit shown in Figure 3:

a) For $V_i=2\text{V}$ what is the current through Q1?

b) For $V_i=2\text{V}$, what is $V_o$?

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 3dB frequencies 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 $V_o(t)$.
Question 4 (20 marks)

![Diagram of a circuit with labeled components]

Figure 5. $I=0.2\, \text{mA}$, $\beta=100$, $V_A=100\, \text{V}$.

For the circuit shown in Figure 5:

a) Find the input resistance $R_i$.

b) Find the output resistance $R_o$.

c) Find the amplifier transconductance $G_m$.

d) Find the open-circuit voltage gain for the amplifier.
Question 5 (20 marks)

Figure 6. The op-amp saturation voltages are ±12V, \( R_1 = 10k\Omega \), \( R_2 = R = 100k\Omega \), \( C = 0.1\mu F \).

For the circuit shown in Figure 6:

a) Explain the operation of this circuit.

b) Sketch the waveforms \( V_c(t) \) and \( V_o(t) \).

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

d) Find the frequency of the output signal \( V_o \).
Question 6 (20 marks)

Figure 7. \( k_n = 50 \mu A/V^2 \), \( k_p = 20 \mu A/V^2 \), \( V_m = -V_p = 1V \), \( C_{ox} = 1fF/\mu m^2 \), \( V_{DD} = 5V \)

Gate-drain overlap \( C_{gd} = 0.5fF/\mu m \), drain-body \( C_{db} = 10fF \), wiring \( C_{ox} = 5fF \).

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) Evaluate the propagation delay for this inverter driving a second identical inverter.

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)**

![Circuit Diagram](image)

Figure 9. $R_B=20k\Omega$, $R_F=5k\Omega$, $V_{DD}=5V$, $V_{bias}=1V$
$V_I=0.8V$, $k^*=40 \mu A/V^2$. Transistor dimensions in µm.

a) What is a common name for the circuit shown in Figure 9? Briefly explain how it works.

b) Calculate the drain current for $Q_1$ (choose a starting value for the gate voltage and iterate to a solution).

c) If $a_3-a_0$ are connected to $V_{DD}$, find $I_D$. For each value of $A_{in}=0000$ to $A_{in}=1111$ determine the output $V_o$.

d) What are the limitations of the application of this circuit?
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)