

## 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.

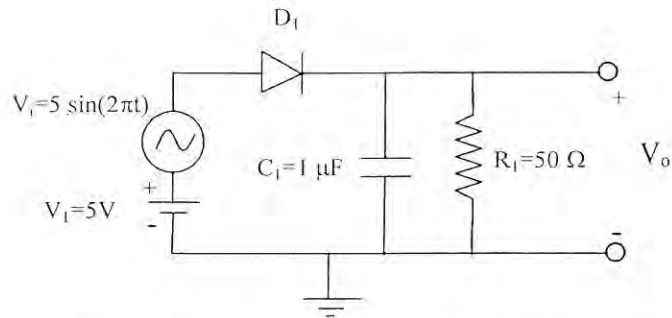
**Question 1 (20 marks)**

Figure 1. The diode has a voltage drop  $V_D=0.7V$  in forward bias.

For the circuit shown in Figure 1:

- Sketch  $V_i$  and  $V_o$  as a function of time, indicating peak voltages.
- Find the maximum and minimum output voltage  $V_o$ .
- What is the peak current through  $R_1$ ?

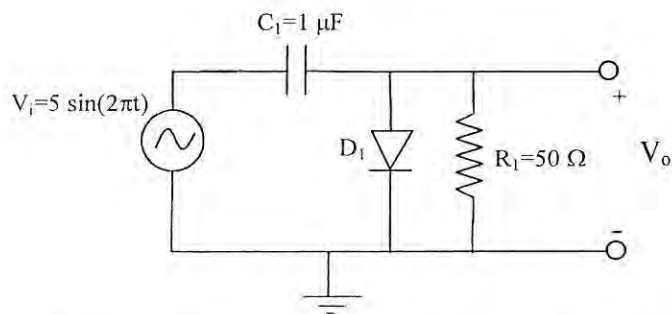


Figure 2. The diode has a voltage drop  $V_D=0.7V$  in forward bias.

For the circuit shown in Figure 2:

- Sketch the output waveform  $V_o(t)$  in steady state. Label peak voltages.

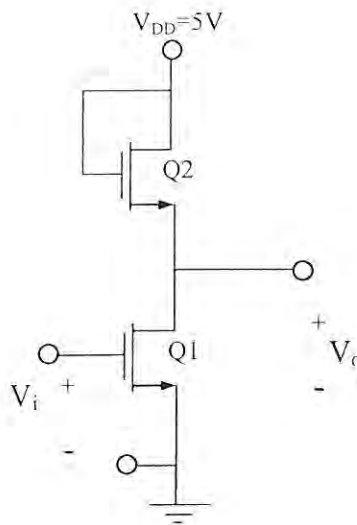
**Question 2 (20 marks)**

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

For the circuit shown in Figure 3:

- For  $V_i=2V$  what is the current through Q1?
- For  $V_i=2V$ , what is  $V_o$ ?
- Draw a small signal equivalent model for the circuit.
- What is the small signal AC gain of the circuit?

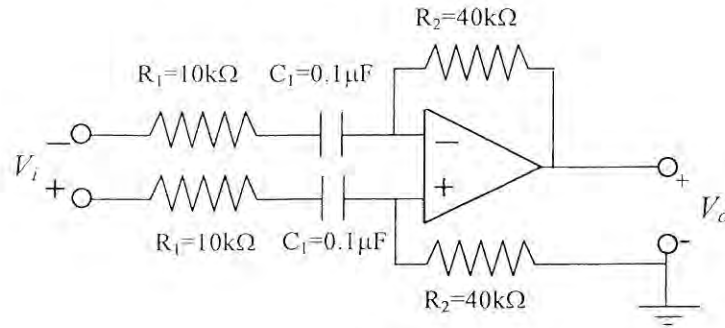
**Question 3 (20 marks)**

Figure 4.

For the circuit shown in Figure 4:

- 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.
- Sketch the frequency response, indicating 3dB frequencies for this circuit.
- If  $V_i(t) = 10\sin(120\pi t)$  V, find  $V_o(j\omega)$ .
- If  $V_i(t) = 10\sin(120\pi t)$  V, find  $V_o(t)$ .

**Question 4(20 marks)**

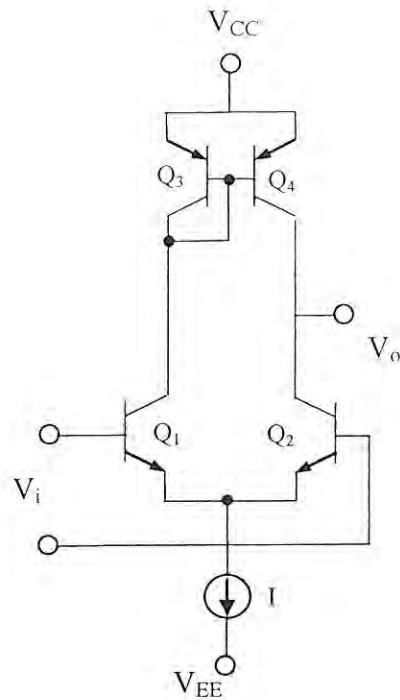


Figure 5.  $I=0.2\text{mA}$ ,  $\beta=100$ ,  $V_A=100\text{V}$ .

For the circuit shown in Figure 5:

- Find the input resistance  $R_i$ .
- Find the output resistance  $R_o$ .
- Find the amplifier transconductance  $G_m$ .
- Find the open-circuit voltage gain for the amplifier.

**Question 5 (20 marks)**

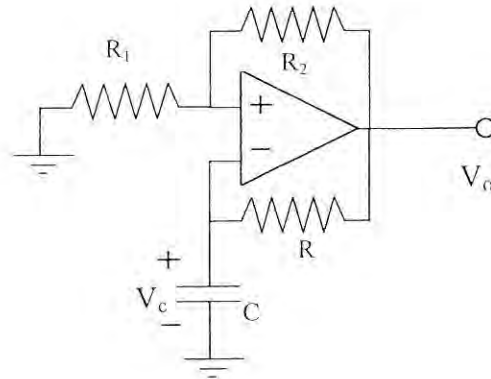


Figure 6. The op-amp saturation voltages are  $\pm 12\text{V}$ ,  $R_1=10\text{k}\Omega$ ,  $R_2=R=100\text{k}\Omega$ ,  $C=0.1\mu\text{F}$ .

For the circuit shown in Figure 6:

- Explain the operation of this circuit.
- Sketch the waveforms  $V_c(t)$  and  $V_o(t)$ .
- Find an expression for  $V_c(t)$ .
- Find the frequency of the output signal  $V_o$ .

**Question 6 (20 marks)**

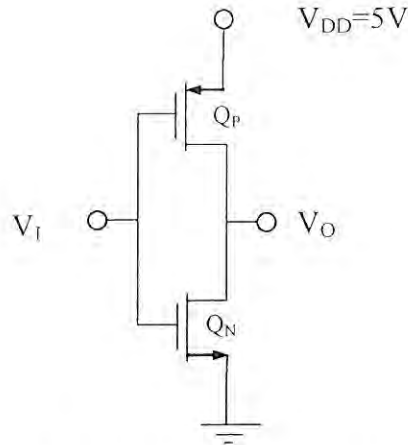


Figure 7.  $k_n' = 50 \mu\text{A}/\text{V}^2$ ,  $k_p' = 20 \mu\text{A}/\text{V}^2$ ,  $V_{tn} = -V_{tp} = 1\text{V}$ ,  $C_{ox} = 1\text{fF}/\mu\text{m}^2$ ,  $V_{DD} = 5\text{V}$   
 Gate-drain overlap  $C_{gd} = 0.5\text{fF}/\mu\text{m}$ , drain-body  $C_{db} = 10\text{fF}$ , wiring  $C_{ox} = 5\text{fF}$ .

- If the minimum gate length for this technology is  $1 \mu\text{m}$ , size  $Q_N$  and  $Q_P$  to obtain a symmetric transfer characteristic.
- Evaluate the propagation delay for this inverter driving a second identical inverter.

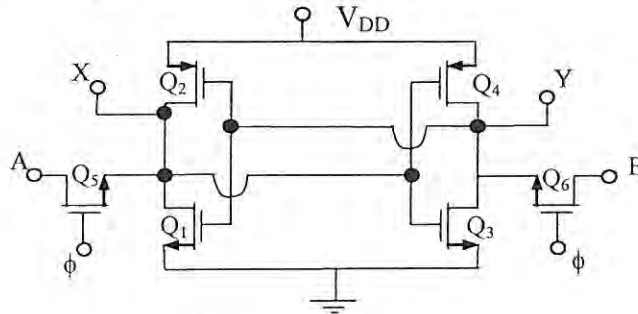


Figure 8.

For the circuit shown in Figure 8:

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

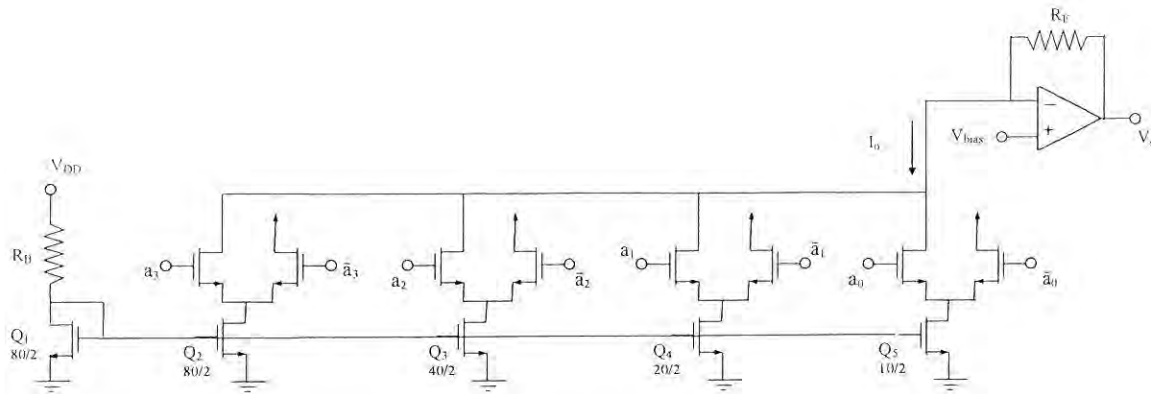


Figure 9.  $R_B=20k\Omega$ ,  $R_F=5k\Omega$ ,  $V_{DD}=5V$ ,  $V_{bias}=1V$   
 $V_t=0.8V$ ,  $k'=40 \mu A/V^2$ . Transistor dimensions in  $\mu m$ .

- What is a common name for the circuit shown in Figure 9? Briefly explain how it works.
- Calculate the drain current for  $Q_1$  (choose a starting value for the gate voltage and iterate to a solution).
- If  $a_3$ - $a_0$  are connected to  $V_{DD}$ , find  $I_0$ . For each value of  $A_{in}=0000$  to  $A_{in}=1111$  determine the output  $V_0$ .
- 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)