

# 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)**

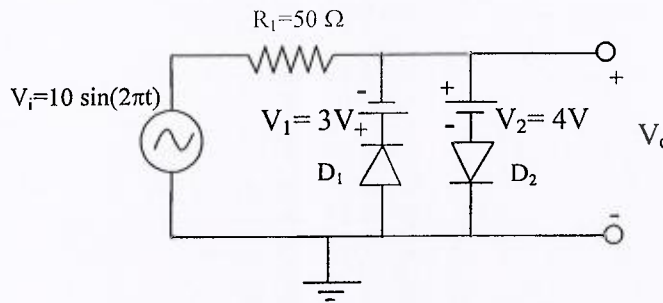


Figure 1. The diodes have a voltage drop  $V_D=0.7V$  in forward bias.

For the circuit shown in Figure 1:

- a) Sketch  $V_i$  and  $V_o$  as a function of time, indicating peak voltages.
- b) How should  $D_1$  be rated for power consumption?
- c) What is the peak current in  $R_1$ ?

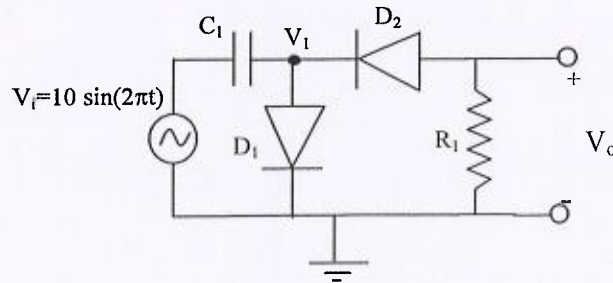


Figure 2. The diodes have a voltage drop  $V_D=0.7V$  in forward bias.

For the circuit shown in Figure 2:

- d) Sketch the output waveform  $V_o(t)$  in steady state. Label key voltages and times, and indicate changes in operating region for the diodes.

**Question 2 (20 marks)**

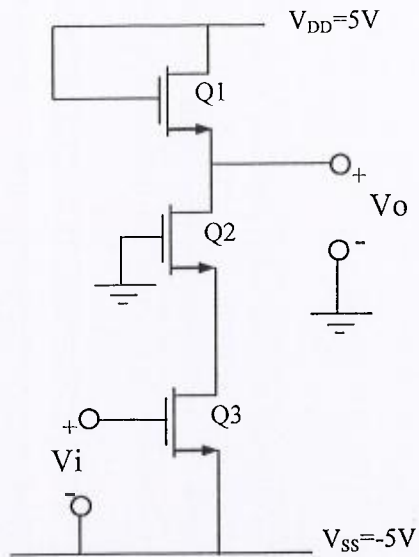


Figure 3.  $k_n' = \mu_n C_{ox} = 1 \text{ mA/V}^2$ ,  $W/L=10$ ,  $V_{tn}=1\text{V}$ ,  $|V_A|=100\text{V}$

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)**

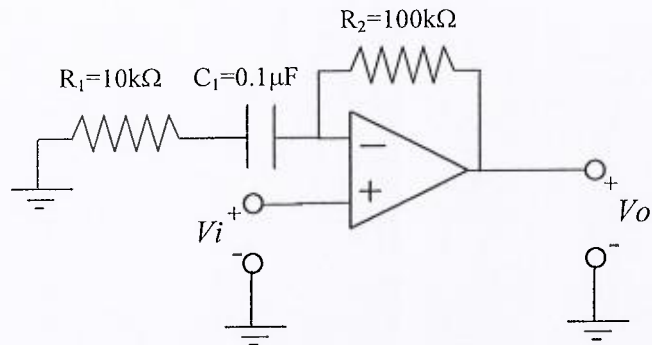


Figure 4.

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 the 3dB frequency 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)**

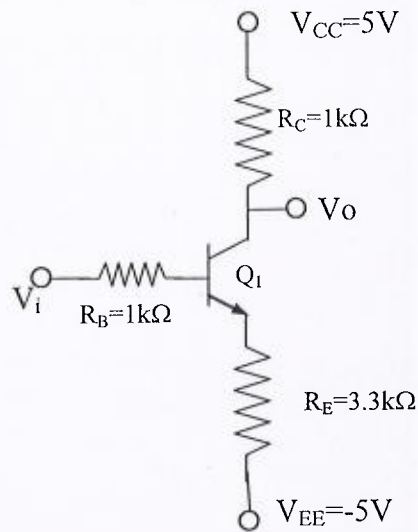


Figure 5.  $V_{be}=0.7V$  (active),  $V_{ce}=0.2V$  (saturation),  $\beta=100$ .

For the circuit shown in Figure 5:

- If  $V_i=0V$  DC, find the DC bias point for Q1?
- Draw the small signal equivalent circuit and evaluate the small signal AC voltage gain.
- Sketch  $I_c$  vs  $V_{ce}$  and show the operating point for the transistor.
- How would you change the bias to obtain maximum signal swing?

**Question 5 (20 marks)**

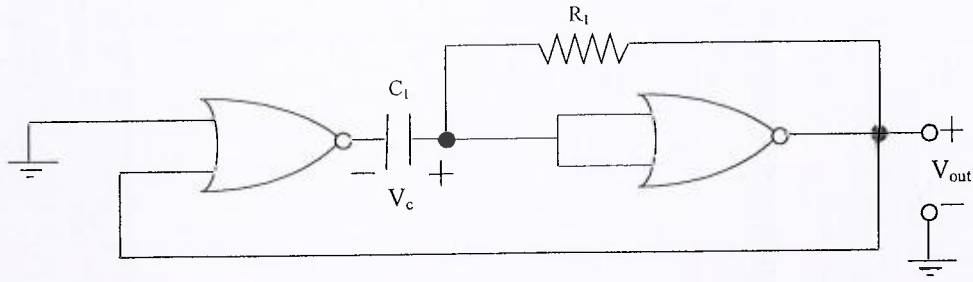


Figure 6. Assume the gates are ideal and switch at  $V_{DD}/2$ .

For the circuit shown in Figure 6:

- Explain the operation of this circuit.
- Sketch the waveforms  $V_c(t)$  and  $V_{out}(t)$ .
- Find an expression for  $V_c(t)$ .
- Find the period of the waveform if  $R_1=10\text{ k}\Omega$  and  $C_1=10\text{ nF}$ .

**Question 6 (20 marks)**

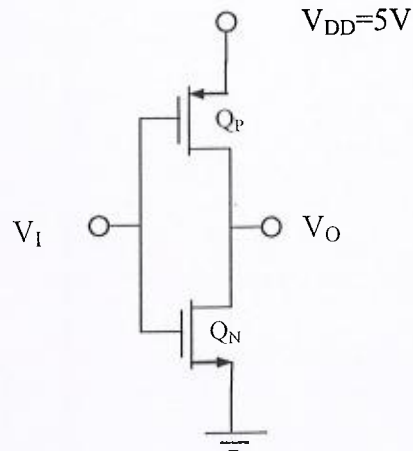


Figure 7.  $k_n' = 50 \mu\text{A}/\text{V}^2$ ,  $k_p' = 20 \mu\text{A}/\text{V}^2$ ,  $V_{tn} = -V_{tp} = 1\text{V}$ ,  $C_{ox} = 1\text{fF}/\mu\text{m}^2$ ,  $V_{DD} = 5\text{V}$ .

- a) 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.
- b) Estimate the maximum capacitance this circuit can drive with a propagation delay of less than  $200 \text{ps}$ .

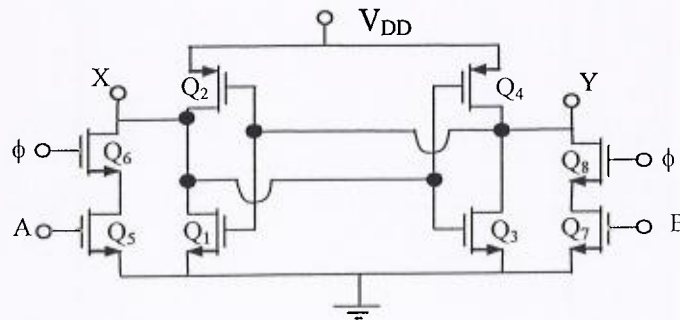


Figure 8.

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)**

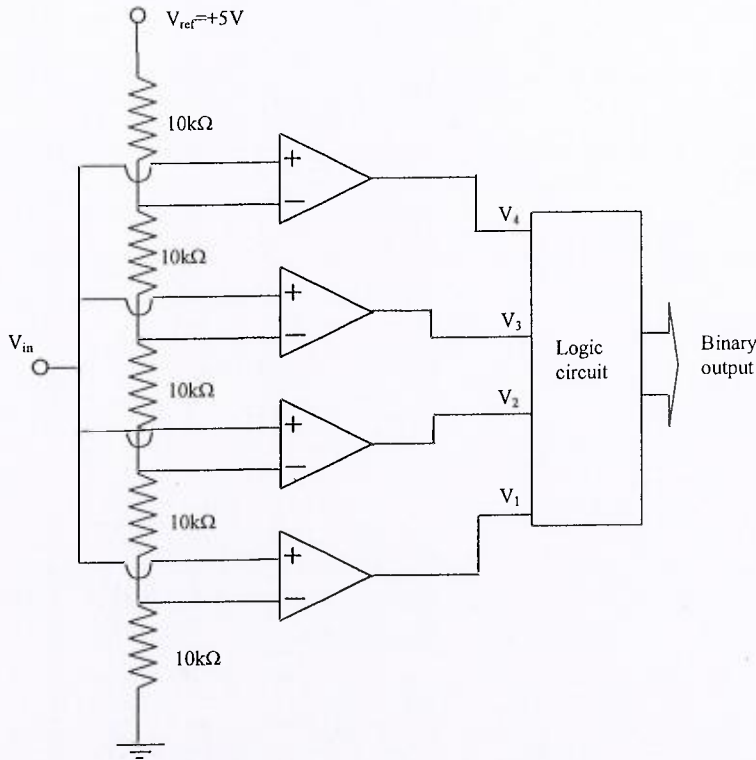


Figure 9.

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