

# CARLETON UNIVERSITY

FINAL  
EXAMINATION  
April 18, 2000

Duration: 3 hours

Department name and course number:      Electronics 97.257

Course Instructor(s): L. Roy, N. Tait      Number of students: 266

AUTHORIZED MEMORANDA:

CALCULATOR

Students **MUST** count the number of pages in this examination paper before beginning to write, and report any discrepancies immediately to a proctor. This question paper has

12      pages.

This examination question paper **MAY NOT** be taken from the examination room.

This exam consists of 5 questions, which should be answered on this exam paper in the space provided. Attempt all questions. Marks allocated to each question are indicated. The total number of marks for the examination is 65.

The solution must be clearly indicated. Multiple solutions or solutions that are not clearly identified, will be marked incorrect. Clearly state all assumptions made. Show your work.

Diode:

$$I_D = I_S \left( e^{V_D/nV_T} - 1 \right)$$

small signal resistance:  $r_d = \frac{nV_T}{I_D}$

$$V_T = \frac{kT}{q} = 25mV \text{ at room temperature}$$

Bipolar Transistor:

Active mode operation:  $V_{BE} = 0.7V$

Saturation mode operation:  $V_{CEsat} = 0.2V$

$$i_c = \beta i_b \quad i_c = \alpha i_e \quad i_E = i_B + i_C$$

$$g_m = \frac{I_C}{V_T} \quad r_p = \frac{\beta}{g_m} \quad r_e = \frac{\alpha}{g_m} = \frac{r_p}{\beta + 1}$$

$$r_o = \frac{V_A}{I_C} \quad \alpha = \frac{\beta}{\beta + 1}$$

Operational Amplifier:

$$V_o = A(V_+ - V_-) \quad R_i = \infty \quad R_o = 0$$

MOSFET:

$$I_{DS} = K \left[ (V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2} \right]$$

$$I_{DS} = K \frac{(V_{GS} - V_T)^2}{2} \quad K = \frac{W}{L} \bar{\mu} \hat{C}_{ox}$$

$$V_{DS,sat} = V_{GS} - V_T \quad g_m = K(V_{GS} - V_T)$$

$$K = \frac{W}{L} k' \quad g_{mb} = \epsilon g_m \quad r_o = \frac{V_A}{I_D}$$

$$r_{DS,triode} = \frac{1}{K(V_{GS} - V_T)} \quad g_m = \sqrt{2KI_{DS}}$$

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1.) (12 marks) General short answer questions.

a) Which MOSFET amplifier configuration would you choose to obtain large positive voltage gain?

b) What is the difference between an enhancement and a depletion mode MOSFET?

c) What is the difference in the mode of operation of a Zener diode and a regular junction diode?

d) Describe three regions of operation for a n-channel MOSFET, in terms of the voltages that would be applied to the terminals.

e) Sketch  $I_C$  vs  $V_{CE}$  for a BJT for several values of  $V_{BE}$ , indicating modes of operation.

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1.) Continued

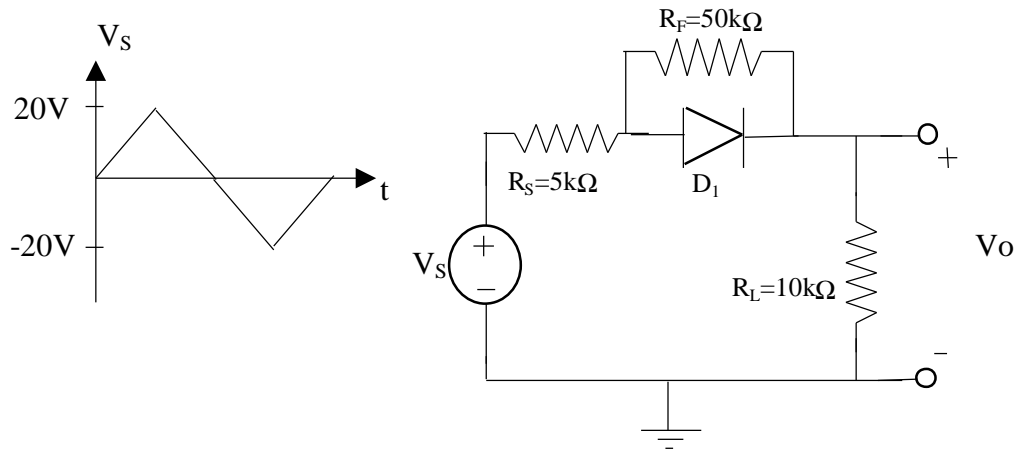
f) What is the body effect in a MOSFET?

g) Why is input resistance an important parameter for a voltage amplifier?

h) Is a transistor a linear device?

i) What is MOSFET an acronym for?

## 2.) (15 marks) Diodes.



a) For the circuit shown above  $V_s$  is a symmetrical triangular wave of 40V peak to peak and the diode has a voltage drop of 0.7V when conducting.

i) Over what range of values of  $V_s$  is the diode on? Express  $V_o$  in terms of  $V_s$ .

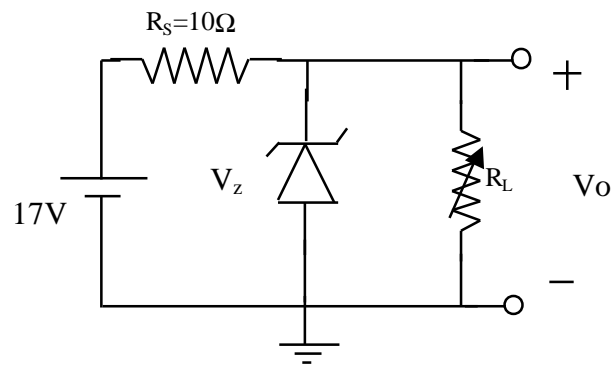
ii) Over what range of values of  $V_s$  is the diode off? Express  $V_o$  in terms of  $V_s$ .

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2.) Continued

iii) Sketch the output waveform  $V_o$  and indicate the peak voltages.

## 2.) Continued



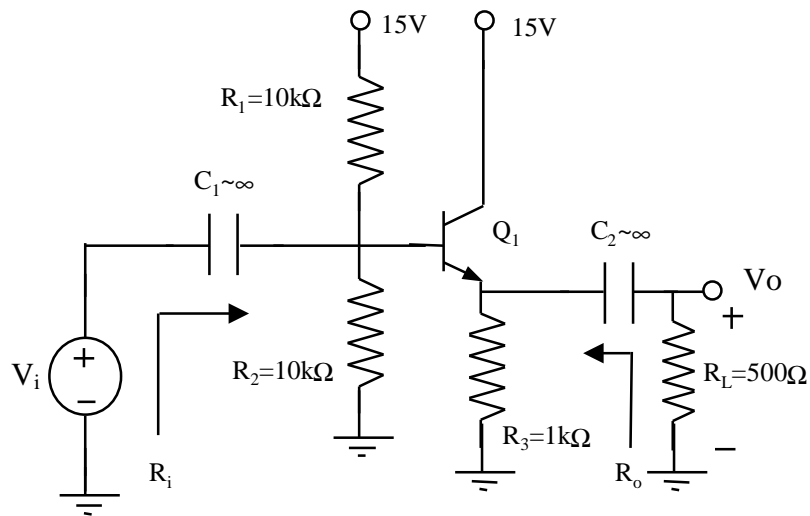
b) In the Zener diode circuit shown above  $V_Z = 12\text{V}$  for  $1\text{mA} < I_Z < 600\text{mA}$ . Determine:

i) the output voltage  $V_o$  when  $R_L = 500\Omega$ ,

ii) the maximum power that the diode should be able to dissipate and the value of  $R_L$  for which this power occurs,

iii) the output voltage  $V_o$  when  $R_L = 10\Omega$ .

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3.) (14 marks) Bipolar Junction Transistor. Use  $\beta=100$ .a) Draw the circuit for DC analysis and find  $I_C$ .b) Find the values of  $r_\pi$ ,  $g_m$ , and  $r_e$ .

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3.) Continued

c) Draw the small signal circuit for AC analysis (with the equivalent model of your choice). Determine  $R_i$  and  $R_o$  for small signal operation.

d) Determine the small signal AC gain  $V_o/V_i$ .

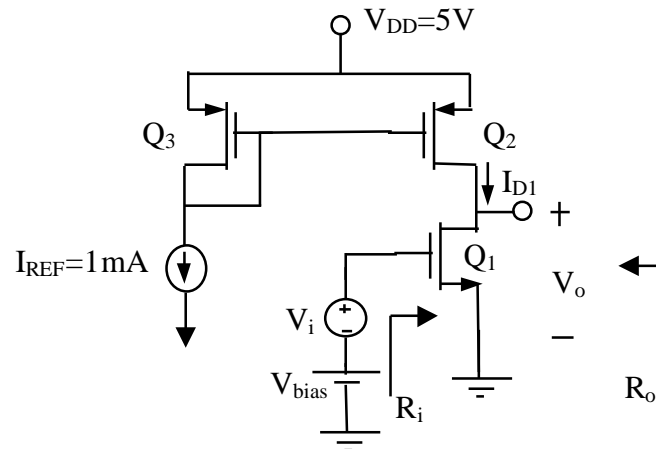
e) Suggest a useful application for this circuit.

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- 4.) (12 marks) MOSFET. All transistors have  $V_T=1\text{V}$ ,  $V_A=30\text{V}$ ,  $k_n' = k_p' = 100\mu\text{A}/\text{V}^2$ , and  $L=1\mu\text{m}$ .  $Q_1$  has  $W_1=100\mu\text{m}$  and  $Q_3$  has  $W_3=50\mu\text{m}$ .  $V_{\text{bias}} > V_T$ .



- a) Find the width of  $Q_2$  ( $W_2$ ) such that  $I_{D1} = 0.5\text{mA}$ . For this calculation neglect the finite output resistance of the transistors. In order to find  $W_2$  what other assumption has been made regarding
- the body contact for each MOSFET
  - the operating mode of each MOSFET.

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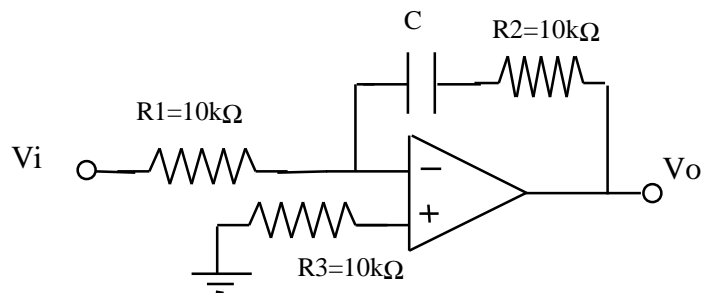
4.) Continued

b) Draw the small signal equivalent circuit for AC analysis. Determine  $g_m$  and  $r_{o1}$  for  $Q_1$  and  $r_{o2}$  for  $Q_2$ .

c) Calculate the small signal gain  $V_o/V_i$  and  $R_i$  and  $R_o$ .

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5.) (12 marks) Operational Amplifier.



a) Find the input impedance and voltage gain expression for the circuit shown, as a function of radial frequency  $\omega$ , assuming the op-amp is ideal.

b) Sketch the magnitude and phase response of gain of the circuit.

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5.) Continued

c) Choose a value of C to give a corner frequency of 20 kHz.

d) Calculate the input impedance and voltage gain as a function of radial frequency  $\omega$ , if the op-amp has a finite open loop gain of 10,000.