Name: R Achar Student #: ________ Section: ____

SOLUTIONS

Question	Max Marks	Score
1	10	
2	20	
3	25	
4	25	
5	20	
Total	100	

CARLETON UNIVERSITY

FINAL EXAMINATION
April 12, 2002

Duration: 3 hours

Department name and course number: Electronics 97.257

Course Instructor(s): R. Achar, N. Tait   Number of students: 380

AUTHORIZED MEMORANDA:

NON-PROGRAMMABLE 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 (total marks = 100).

Note: The solution must be clearly indicated. Multiple solutions or solutions that are not clearly identified, will be marked incorrect. Using approximate relations (unless they are given below or specified in a question) is not accepted. Clearly state all assumptions made. Clearly mark the units for final answers. **SHOW YOUR WORK!**

Diode:

Forward current: $I_D \approx I_S\left(e^{V_D/nV_T}\right)$

Small signal resistance: $r_d = \dfrac{nV_T}{I_D}$

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

Bipolar Transistor:

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

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

$i_C = \beta i_B \quad i_C = \alpha i_E \quad i_E = i_B + i_C$

$g_m = \dfrac{I_C}{V_T} \quad r_\pi = \dfrac{\beta}{g_m} \quad r_o = \dfrac{V_A}{I_C}$

$r_e = \dfrac{\alpha}{g_m} = \dfrac{r_\pi}{\beta+1} \quad \alpha = \dfrac{\beta}{\beta+1}$

Operational Amplifier:

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

MOSFET:

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

$$I_{DS} = k'\frac{W}{L}\frac{(V_{GS}-V_T)^2}{2} \qquad k' = \mu C_{ox}$$

$$V_{DS,sat} = V_{GS} - V_T \qquad g_{mb} = \chi g_m$$

$$g_m = k'\frac{W}{L}(V_{GS}-V_T) = \sqrt{2k'\frac{W}{L}I_{DS}}$$

$$r_{DS,triode} = \left[k'\frac{W}{L}(V_{GS}-V_T)\right]^{-1}; \quad r_o = \frac{V_A}{I_D}$$

1) -A) Answer the following questions by filling in the corresponding circles with your selection *a or b or c or d* (5 marks).

(i) An important advantage of bipolar transistors over MOS transistors is that,

(a)

a) they have higher transconductance

b) they have higher input impedance

c) they have higher electron mobility

d) they emit light when biased.

(ii) For a PMOS enhancement transistor to be in triode mode

(d)

a) $V_{GS} > V_T$; $V_{DS} < V_{GS}-V_T$

b) $V_{GS} > V_T$; $V_{DS} > V_{GS}-V_T$

c) $V_{GS} < V_T$; $V_{DS} < V_{GS}-V_T$

d) $V_{GS} < V_T$; $V_{DS} > V_{GS}-V_T$

(iii) The buffer (impedance matching) stages in electronic circuits can be designed with

(c)

a) Common Emitter Configurations using BJTs

b) Common Base Configurations using BJTs

c) Common Collector Configurations using BJTs

d) Common Gate Configurations using FETs

(iv) In general, the open circuit voltage gain of a common base amplifier configuration

(c, b)

a) is independent of bias current

b) is independent of load resistance

c) is larger than unity

d) is smaller than unity

(v) A common use for a current mirror circuit is

(d)

a) to turn on diodes in AC rectifiers

b) to act as gates in logic circuits

c) to decrease the input resistance of small signal amplifier circuits

d) to bias transistors in integrated circuits

1) -B) Answer the following questions by entering TRUE or FALSE in the space provided (5 marks).

i) A p-channel MOSFET uses a n-type substrate or well. TRUE

ii) Conduction in a MOSFET channel is due primarily to majority carriers. TRUE

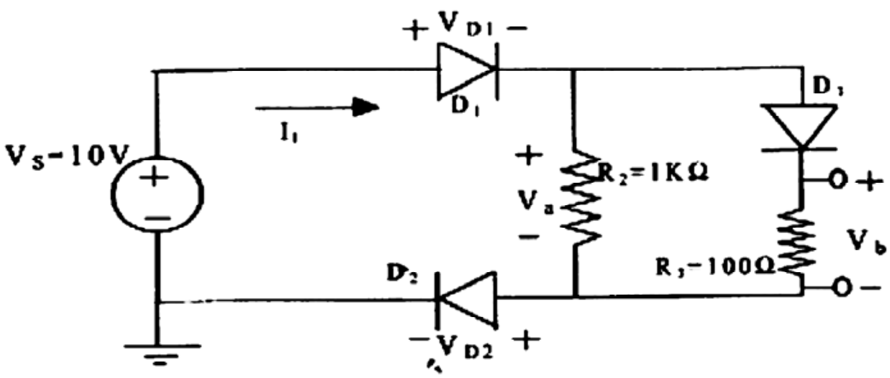
iii) Early effect is generally used estimate the input impedance of transistors. FALSE

iv) In saturation, the collector current in a bipolar transistor is mainly controlled by V_{CE}. FALSE

v) A reverse biased diode acts like a voltage dependent capacitor. TRUE

2) Diodes: For the circuit shown below, the following data is given:
Both diodes D_1 and D_2 have $n = 1.75$ and their reverse saturation currents are such that $I_{s1} = 10 I_{s2}$.
The forward drop across diode D_1 is given to be $V_{D1} = 0.7V$.

The diode D_3 is represented by linear piecewise model [Battery = 0.7V, Resistance = 60 Ohms].



Using the above data, compute the following (12 marks):

i) Find V_{D2} : Given: $n = 1.75$, $I_{s_1} = 10 I_{s_2}$, $V_{D_1} = 0.7$ V_{D2} = 0.8

We have $I_{D_1} = I_{D_2}$

$\therefore I_{s_1} e^{V_{D1}/nV_T} = I_{s_2} e^{V_{D2}/nV_T}$

$\therefore \frac{I_{s_1}}{I_{s_2}} = e^{(V_{D_2} - V_{D_1})/nV_T}$

$\therefore \ln\left[\frac{10 I_{s_2}}{I_{s_2}}\right] = (V_{D_2} - V_{D_1})/nV_T$

$\rightarrow nV_T \cdot \ln[10] = V_{D_2} - V_{D_1}$

$V_{D_2} = V_{D_1} + nV_T \ln[10]$

$= 0.7 + 1.75 \times 25 \times 10^{-3} \times 2.3$

$= 0.7 + 0.1 = 0.8V$

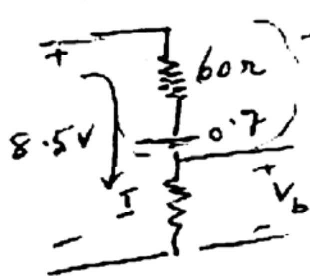
ii) Find V_a : KVL for the first loop; V_a = 8.5V

$V_s - V_{D_1} - V_a - V_{D_2} = 0$

$\therefore 10 - 0.7 - 0.8 = V_a$

$V_a = 8.5V$

ii) Find V_b : V_b = 4.88V



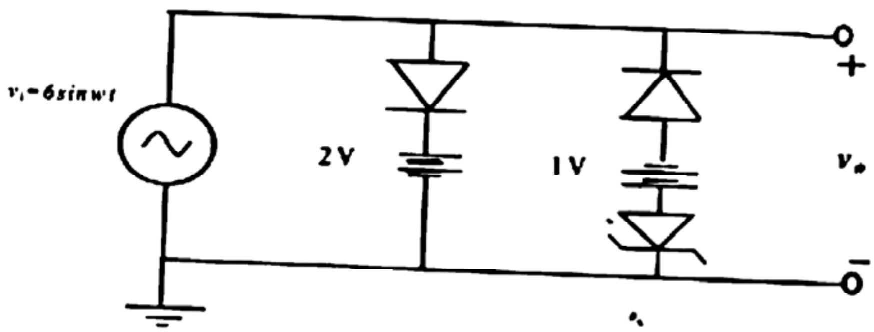
$I = \frac{8.5 - 0.7}{60 + 100}$

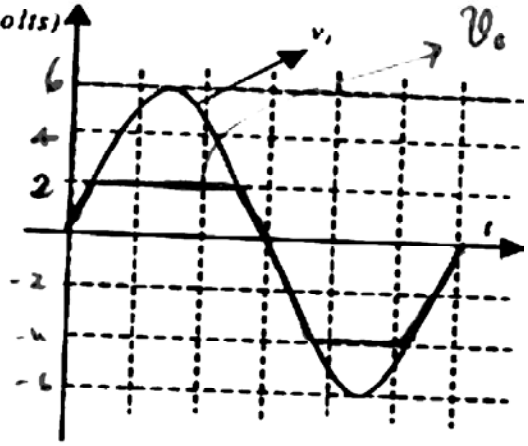
$= \frac{7.8}{160} = 0.0488$

$\therefore V_b = 100 \times 0.0488 = 4.88V$

1) b) **Diodes** *(continued...)*:

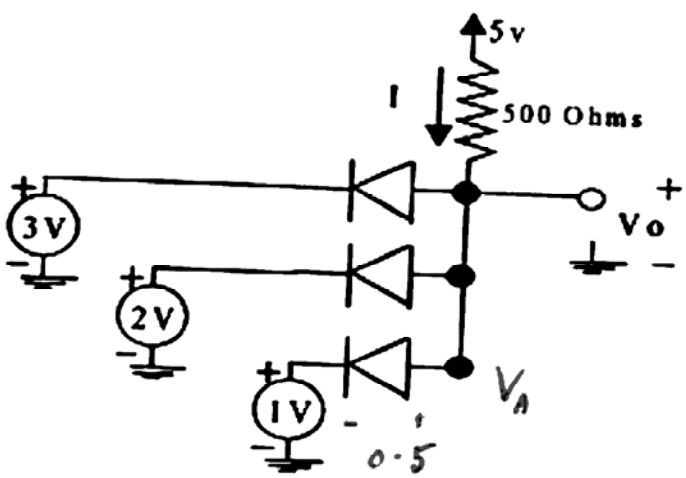
In the following circuit, assume that the diodes D_1 and D_2 are ideal and the zener diode D_3 has a reverse breakdown voltage of 3Volts. If the input is $V_i = 6sin(wt)$, what are the Peak-to-peak values for the output voltage? Sketch the output waveform on the graph shown on left side. (4 Marks).





$V_o \rightarrow +2$ V to -4V

c) Assuming that the forward drop across the diodes is 0.5Volts, what is the value of the current I and output voltage V_o in the following circuit? (4 Marks)



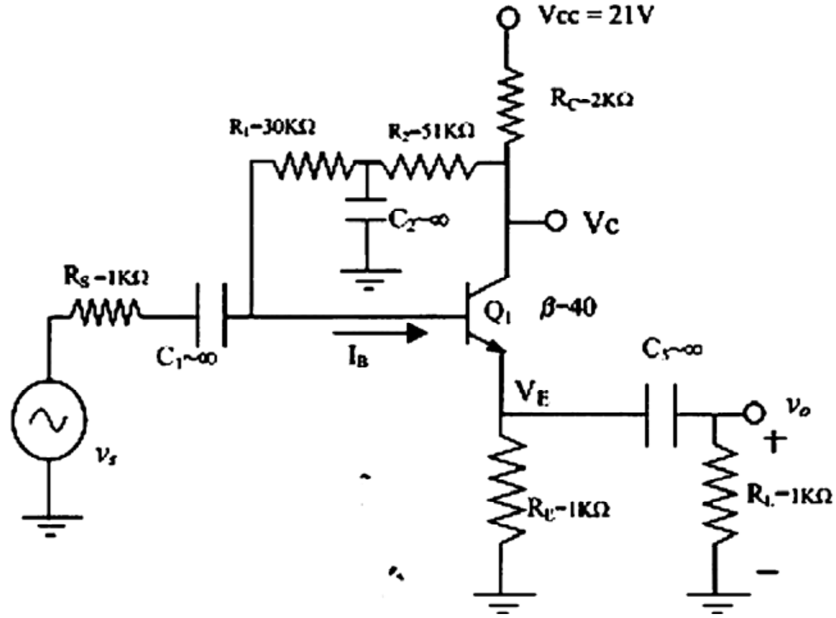
$V_A = 0.5 + 1V = 1.5V = V_o$

$I = \frac{5V - 1.5V}{500\Omega} = \frac{3.5}{500} = 0.7 \times 10^{-2} = 7mA$

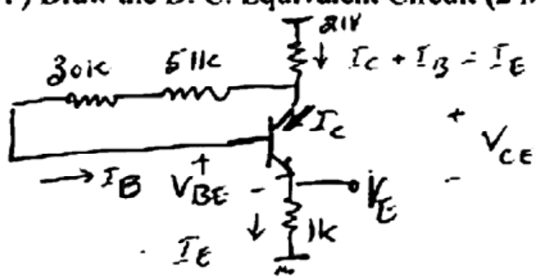
I = 7mA

V_o = 1.5V

3.) Bipolar Junction Transistor



a) For the circuit shown above: i) Draw the D. C. Equivalent Circuit **(2 Marks)**



ii) Compute I_B, V_C and V_{CE} **(8 Marks)**

$$V_{cc} - (I_c + I_B) R_c - I_B (R_1 + R_2) - V_{BE} - I_E R_E = 0$$

$$V_{cc} - V_{BE} = I_B (R_1 + R_2) + (\beta + 1) I_B (R_E + R_c) = 0$$

$$I_B = \frac{21 - 0.7}{81 + 41(2+1)} = \frac{20.3}{204k} = 0.0995 \text{ mA} \simeq 0.1mA$$

I_B= 0.0995mA

V_C= 12.8V

$$I_c = \beta I_B = 40 \times 0.0995 \times 10^{-3} = 3.98mA \simeq 4mA$$

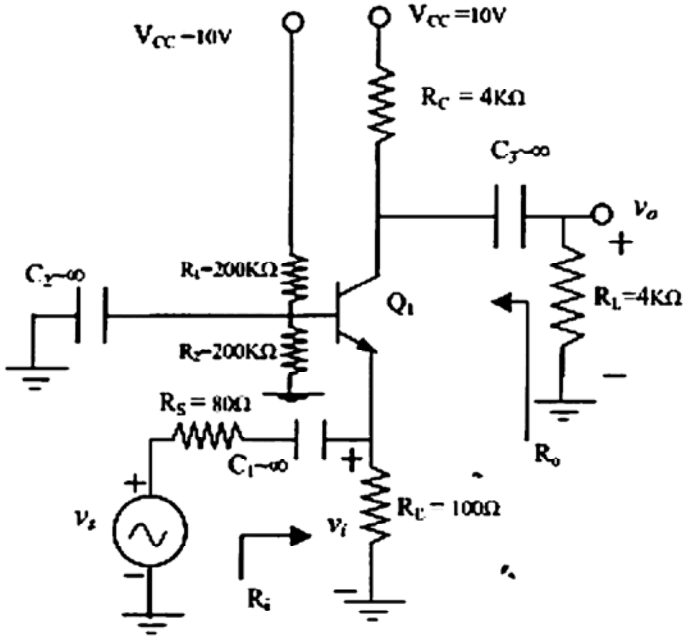
V_{CE}= 8.76V

$$I_E = (\beta+1) I_B = 41 \times 0.0995 \times 10^{-3} = 4.08 mA \simeq 4.1mA$$

$$V_c = V_{cc} - (I_c + I_B) R_c = 21 - 4.08 \times 2 = 12.84V \simeq 12.8V$$

$$V_{CE} = V_c - V_E = V_c - I_E R_E = 12.84 - 4.08 = 8.76 V$$

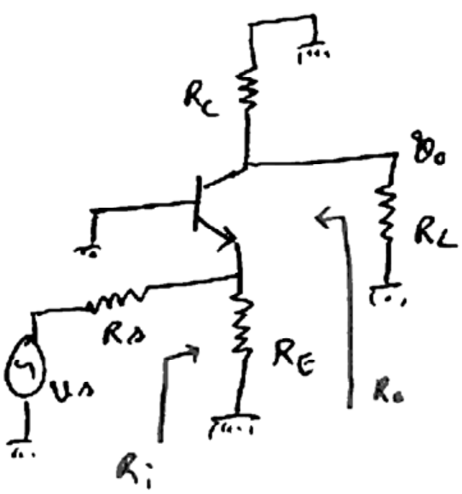
3) b) **Bipolar Junction Transistor** *(continued....)*



$r_e = 25\Omega$
$\beta = 50$

For the BJT, assume that r_e = 25 Ohms and β=50. Using these data, answer the following:

i) Draw the equivalent circuit for small signal AC analysis (*preferably, use T-Model for BJT*) (3 marks)



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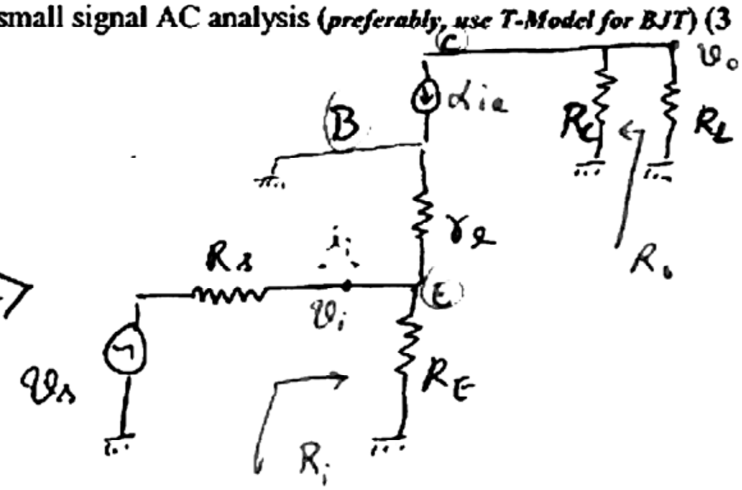
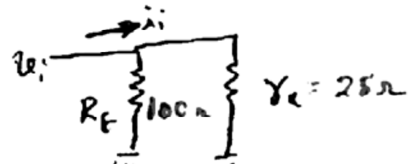


ii) Find the output resistance R_o, input resistance R_i for the circuit (3 marks):

$R_o = R_c = 4k\Omega$

R_o = 4kΩ

$R_i = \frac{v_i}{i_i}$



R_i = 20Ω

$= R_E \| r_e = \frac{100 \times 25}{100 + 25} = 20\Omega$