EE 115A
Winter 2011
Midterm Exam
Feb 7th 2010

Instructions: This exam consists of five problems, blank sheets for the solutions and additional blank sheets. You have 1 hour 45 minutes to finish your exam.

Name:
UID:
Left student's name:
Right student's name:

Problem1:	18 /20
Problem2:	20 /30
Problem3:	20 /20
Problem4:	30/30
Problem5 (Bonus):	0 /20

Total: 88

The professor did not provide solutions to #2, so I included mine. They are 2/3 correct.

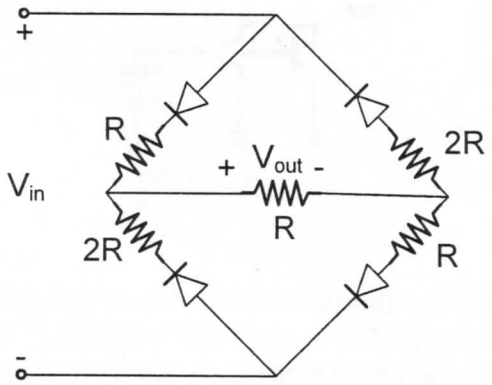
Problem 1 (20)

For the circuit in the following figure, please plot the input – output characteristics (Vout vs. Vin) for -5V < Vin < 5V. Please find the important break-points and the slope (show steps), and label them on the waveform.

(a) Assume ideal diodes.

(b) Assume constant-voltage diode model ($V_{D,on}$ = 0.7V).

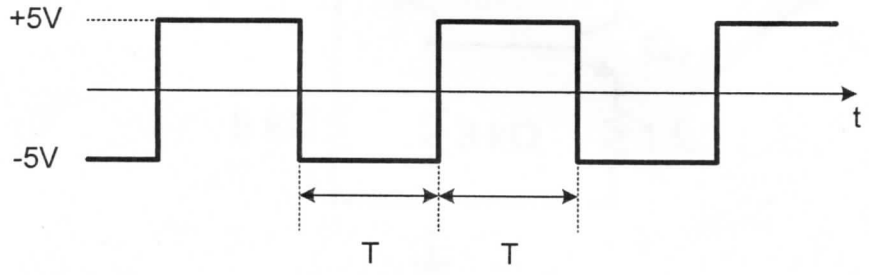
(10 + 10 = 20 points)

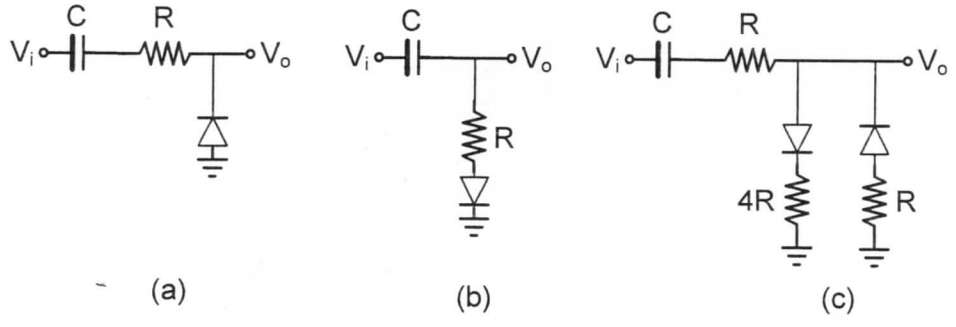


Problem 2 (30)

For the circuits in the following figure, each utilizes an ideal diode. Please sketch the output in the steady-state for the shown input. Label the most positive and the most negative output levels and mathematically justify your sketch. Please provide two sets of outputs for a) RC<<T, b) $T < RC < \infty$.

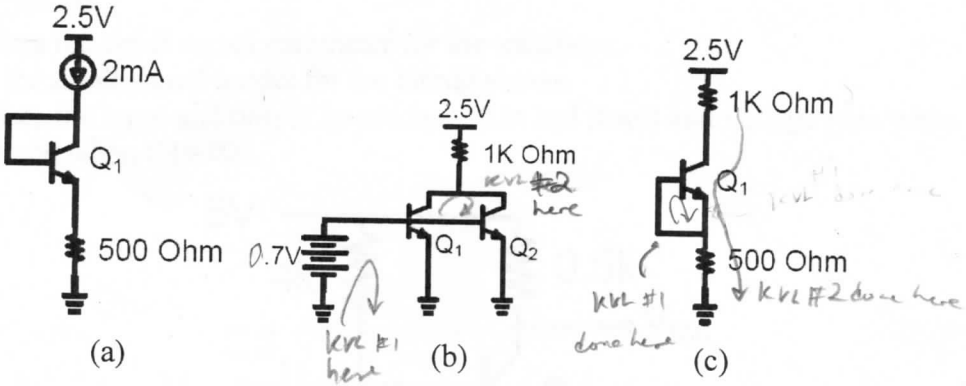
(15 + 15 = 30 points)





Problem 3 (20)

Assume $I_s=8*10^{-16}$, $\beta= 100$, $VA=\infty$, $V_{CE,SAT}=0.2$ V. Find I_C, V_{BE}, V_{CE} and identify the region of operation.



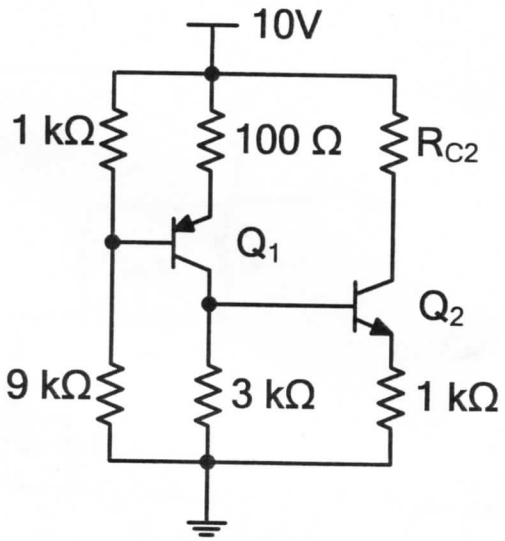
Problem 4 (30)

For the amplifier circuit shown below, assume that $I_S(pnp) = 5*10^{-16}$, $\beta(pnp) =100$, $V_A(pnp) = \infty$, $I_S(npn) = 5*10^{-16}$, $\beta(npn) = 80$, $V_{CE,SAT}=0.2$ V, and $V_A(npn) = \infty$.

(a) For $R_{C2} = 2K\Omega$, solve for the voltages of all three terminals of both transistors Q_1 and Q_2 (V_E, V_C, and V_B for both the npn and pnp).

(b) For what values of R_{C2} will the device Q_2 be in saturation region?

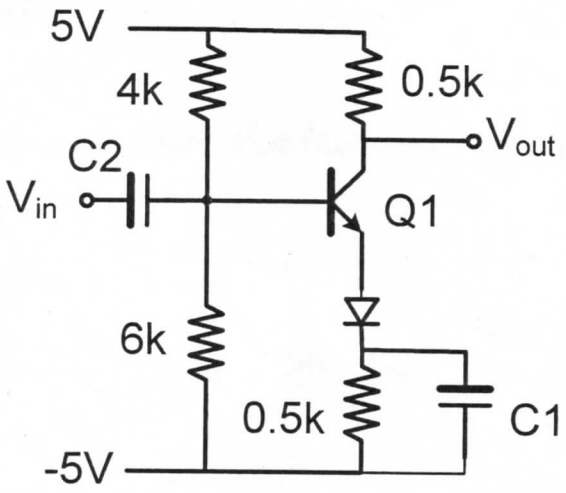
*You may neglect I_B with respect to I_R.



Problem 5 (Bonus, 20 total)

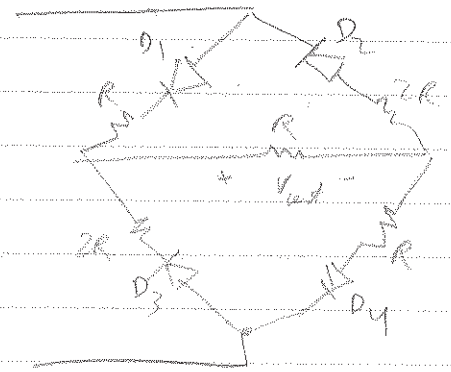
For the circuit in the following figure, Is=5*10-16A, β=100, $V_{CE}(sat) = 0.2V$, $V_{D,on}$=0.7V and $V_A = \infty$, C2= ∞ .

a) Calculate the small signal parameter for the transistor.
b) Draw the small signal model for the circuit shown.
c) Calculate the input and output impedance (Rin and Rout) and voltage gain when C1=0; and when C1= ∞ .

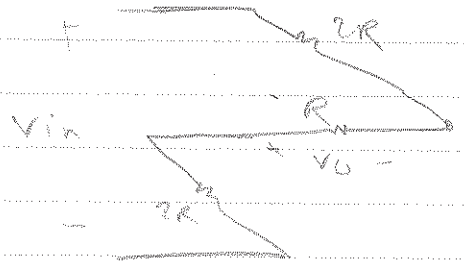


Midterm

(P1) a) for $V_i = -5$

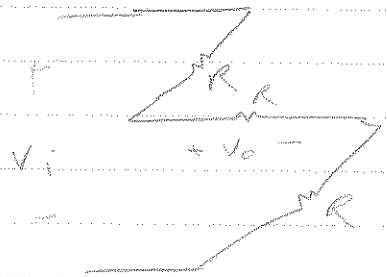


D_2 & D_3 are on, D_1 & D_4 are off

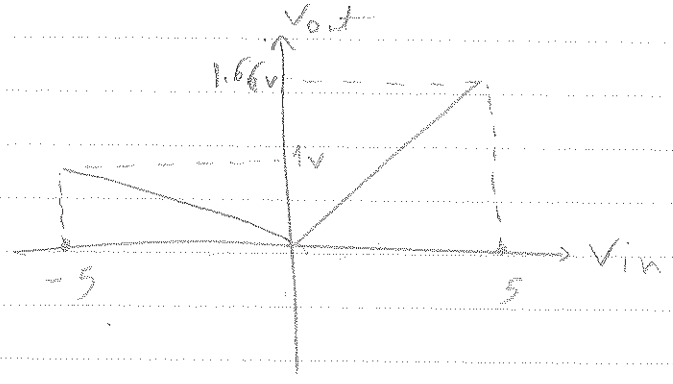


$$V_o = -V_i \times \frac{R}{5R} = \frac{-V_i}{5}$$

as V_i increases, @ $V_i = 0$ D_2 & D_3 turn off & D_1 & D_4 turn on

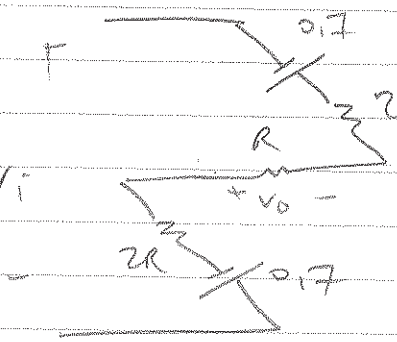


$$V_o = V_i \times \frac{R}{3R} = \frac{V_i}{3}$$



(b) for $v_i = -5$, D_2 & D_3 are on & D_1 & D_4 are off

$$v_o = -(v_i + 1.4) \times \frac{R}{5R}$$



$$\boxed{v_o = -\frac{v_i}{5} - 0.28}$$

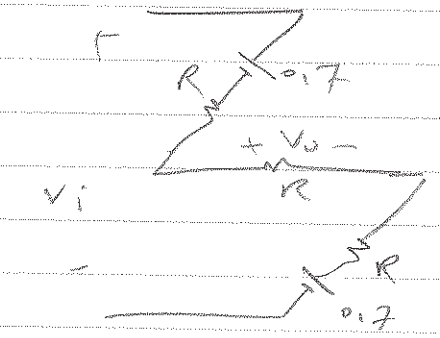
as v_i increases to $-1.4 \rightarrow I = 0 \rightarrow D_2$ & D_3 turn off and D_1 & D_4 are still off

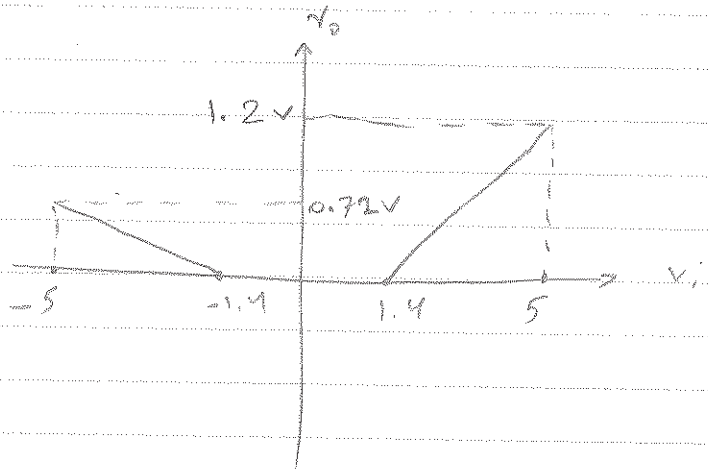
$I = 0 \rightarrow v_o = 0$

@ $v_i = 1.4\,v \rightarrow D_1$ & D_4 turn on

$$v_o = (v_i - 1.4) \times \frac{R}{3R}$$

$$= \frac{v_i}{3} - 0.466$$





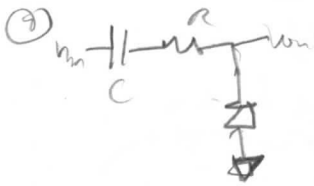
(This page is not entirely correct, but the professor did not give solutions for #2)

(2)

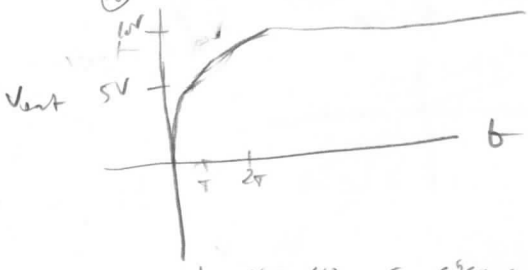
cap doesn't discharge quickly

cap acts like a wire

(a)



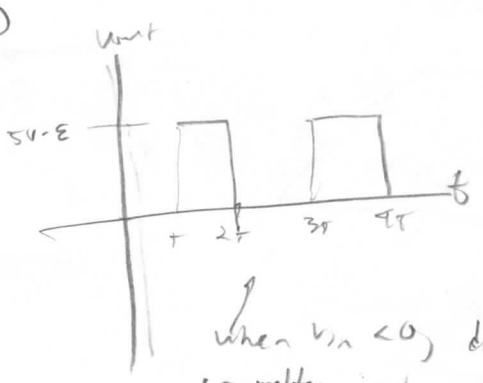
(A)



when $v_{in} \leq 0$, cap charges up, and v_{out} is $0 + v_{cap}$ since grounded

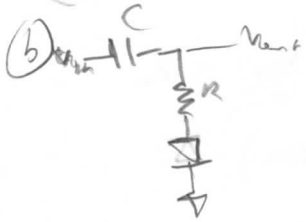
when $v_{in} > 0$, $v_{out} = v_{in} + v_{cap} = 5 + 5 = 10V$

(b)

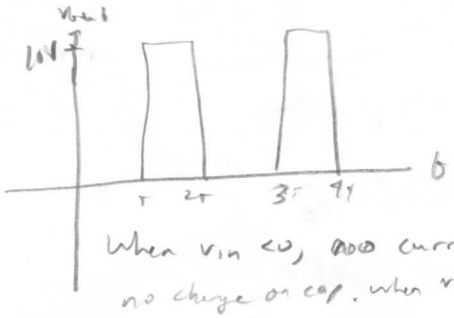


when $v_{in} < 0$, diode is a wire/short ∴ no voltage when v_{in} is ≥ 0 v_{out} is v_{in}, minus small charge on resistor.

(b)

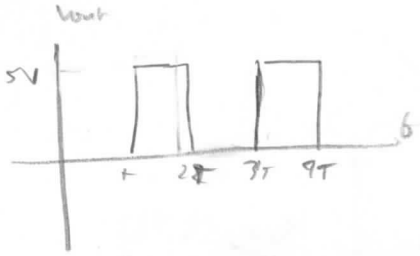


(a)



when $v_{in} < 0$, no current, so no charge on cap. when $v_{in} > 0$, cap charges up

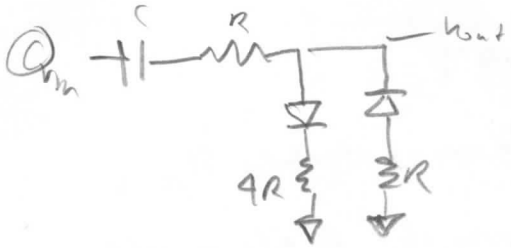
(b)



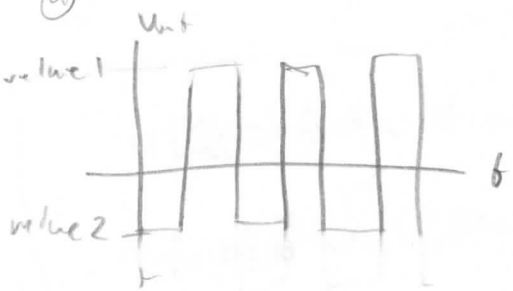
when $v_{in} < 0$, no current flows

when $v_{in} > 0$, $v_{out} = v_{in}$ by KVL

(c)

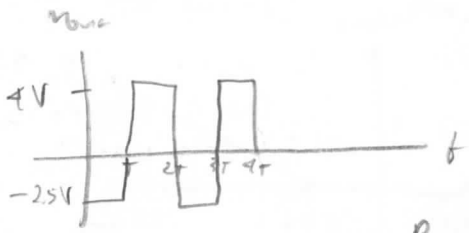


(a)



value 1 > value 2 since resistor $4R > R$

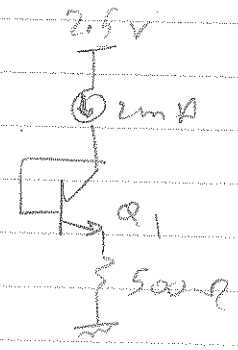
(b)



when $v_{in} < 0$, $v_{out} = \frac{R}{R+R} v_{in} = \frac{1}{2} v_{in}$ by voltage division

when $v_{in} > 0$, $v_{out} = \frac{4R}{R+4R} v_{in} = \frac{4}{5} v_{in}$

(P3) (a)



$$I_C + I_B = 2mA = I_E$$

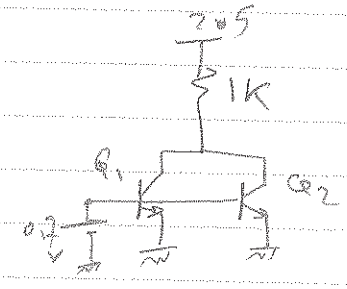
$$I_C = \alpha I_E = \frac{\beta}{\beta+1} I_E = 1.98 mA$$

$$\rightarrow V_{BE} = V_T \ln \frac{I_C}{I_S} = 0.742 V$$

$$\& V_{CE} = V_{BE} = 0.742 V$$

Transistor in (Active)

(b)



$$V_{BE_1} = V_{BE_2} = 0.7 V$$

$$I_{C_1} = I_{C_2} = I_S e^{V_{BE}/V_T}$$

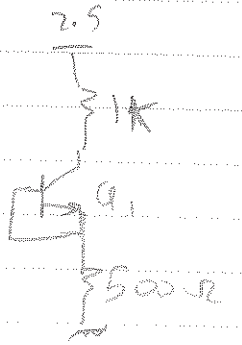
$$= 0.394 mA$$

$$\rightarrow V_{CE_1} = 2.5 - 1k \times 2 \times 0.394 mA$$

$$= 1.712 V = V_{CE_2}$$

Q_1 & Q_2 are in (Active)

(c)



$V_{BE} = 0 \rightarrow I_C = 0$ as BE junction is in reverse

$V_C = 2.5 V$, $V_E = 0$

$\rightarrow V_{CE} = 2.5 V$

$\rightarrow$ CB junction is in reverse

$\rightarrow$ transistor is (off)

Assume $I_B \ll \left(\frac{10V}{10k\Omega} = 1mA\right)$, $\because \beta \gg 1 \Rightarrow I_E \simeq I_C = \beta I_B$

(a)

$\therefore V_{B_1} = 10 \times \frac{9}{9+1} = 9V$

KVL: $10V = I_{E_1} \times 100 + V_{EB_1} + 9V$

$\therefore 1 = 100 I_S e^{V_{EB_1}/V_T} + V_{EB_1}$

$V_{EB} = 0.7 \Rightarrow RHS = 0.725$

$V_{EB} = 0.75 \Rightarrow RHS = 0.87$

$V_{EB} = 0.8 \Rightarrow RHS = 1.95$

$V_{EB} = 0.78 \Rightarrow RHS = 1.12$

$V_{EB} = 0.755 \Rightarrow RHS = 0.96V$ ≠

$\therefore V_{E_1} = V_{B_1} + V_{EB_1} = 9 + 0.96 = 9.96V$

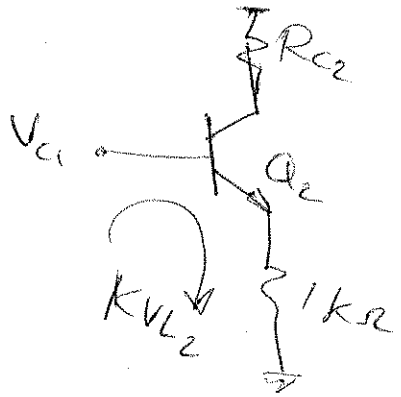
$\therefore I_E = \frac{10 - 9.755}{100} = \frac{245mV}{100} = 2.45mA$ ~~$= 400\mu A$~~

$I_{C_1} \simeq I_{E_1} \Rightarrow V_{C_1} = I_{C_1} \times 3000 = 7.35V$ "Assume $I_{B_2} \ll I_{C_1}$"

Check 1: $V_{C_1} < V_{B_1} \Rightarrow$ Active Region

Check 2: $I_{B_1} \simeq \frac{2450\mu A}{100} \approx 24\mu A \ll 1mA \Longrightarrow \left(I_B \ll \frac{10V}{10k\Omega}\right)$ is a valid assumption

KVL$_2$:



$V_{C1} = 7.35\,V = V_{BE_2} + I_E \times 1000$

$7.35 = V_{BE_2} + 1000 I_{S_n} \times e^{V_{BE_2}/V_T}$

$= V_{BE_2} + 5\times10^{-13}\, e^{V_{BE_2}/V_T}$

$V_{BE_2} > 0.7V \Rightarrow RHS = 0.95$

$V_{BE_2} = 0.75V \Rightarrow RHS = 2.44$

$V_{BE_2} = 0.73V \Rightarrow RHS = 1.51V$

$V_{BE_2} = 0.72V \Rightarrow RHS = 1.25\,V$ ≠

$V_{BE_2} = 0.785\,V \quad RHS = 7.26$

$\therefore V_{B_2} = 7.35V, \quad V_{E_2} = 7.35 - 0.785 = 6.57V$

$\therefore I_{E_2} = \frac{6.57V}{1K} = 6.57\,mA$

$I_{C_2} \simeq I_{E_2} = 6.57\,mA \Longrightarrow V_{C_2} = 10 - I_{C_1} R_{C_2}$

$= 10 - 0.96 = 3.13\,V$ ✗

Check1: $V_{C_2} > V_{B_2} \Longrightarrow$ Active Region

Check2: $I_{B_2} = \frac{I_{C_2}}{\beta_n} = 6\,\mu A \ll (I_{C_1} = 400\,\mu A)$

(b) Edge of Sat. $\Rightarrow V_{C_2} = V_{B_2} = 7.35V$

$\therefore R_{C_2} = \frac{10 - 7.35}{6.57\,mA} = 0.4\,K\Omega$

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