98/100

EE115A – Analog Electronic Circuits
Fall 2017 – Prof. Shervin Moloudi
Mid-term Exam – Monday November 6, 2017

READ THE INSTRUCTIONS BEFORE YOU START

1- You have 1 hour and 50 minutes.
2- Write your name on top of all pages and do not remove the staple.
3- If you need extra pages, ask the proctor.
4- A 5.5in x 8.5in 2-sided formula sheet is allowed.
5- No electronic devices including calculators, laptops, cell phones, etc. are allowed. You can use a regular wrist watch if you so choose.

Question	Points
1	/ 10
2	/ 40
3	/ 25
4	/ 25
Grade	/ 100

(/4)

Name: [redacted] **Student ID:** [redacted]

1- True or False?

T	In an NPN BJT the emitter is N+ to ensure the BE current is dominated by free electrons.
F	In a PNP BJT the base layer is thin to ensure the rate of thermal ionization is sufficiently high.
F	N-type semiconductors are made by adding a dopant element from group V of the periodic table to a crystalline material of atoms from group III.
F	In a PN junction the width of the depletion region is larger on the P side.
~~F~~ T	A semiconductor becomes more conductive as the temperatures rises above the room temperature. gen = recomb

(-2)

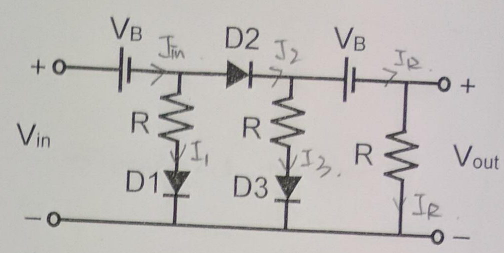
(10 points)

Name: [redacted]

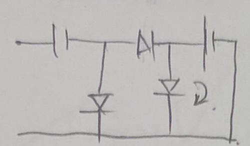
Student ID: [redacted]

2- Find V_{out} versus V_{in}, as V_{in} varies from $-\infty$ to $+\infty$, if the diodes have a turn on voltage of $V_{Don}=0$ and are otherwise ideal (Use a piece-wise linear model). V_B is larger than 0.

(40 points)



1. Assume D_1, D_2, D_3 off



$I_1 = I_2 = I_3 = 0$

By KCL : there's no current in the circuit.

$V_{out} = R \cdot I_R = R \cdot 0 = 0V$

Condition : $V_{D_1}, V_{D_2}, V_{D_3} < V_{D,on} = 0$

① $V_{D_1} = V_{in} - V_B < 0$.

$V_{in} < V_B$.

② $V_{D_2} = V_{in} - V_B - V_B < 0$.

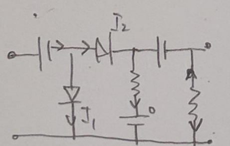
$V_{in} < 2V_B$

③ By KVL

$V_{D_3} = V_B > 0$.

$\therefore V_{D_3}$ is on. assumption fails. ⇒ this case is impossible

2. Assume D_1, D_2 off. D_3 on.



$I_1 = I_2 = 0$. $I_3 > 0$

$I_{in} = I_1 + I_2 = 0$.

$\therefore I_3 = \frac{V_B - V_{D,on}}{2R} = \frac{V_B}{2R} > 0$ → verified D_3 on is true

$V_{out} = -I_3 \cdot R = -\frac{V_B}{2}$

Condition:

① $V_{D_1} = V_{in} - V_B < 0$.

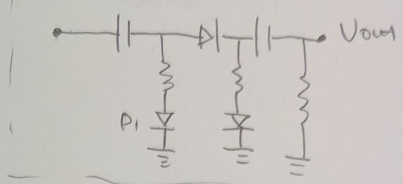
$V_{in} < V_B$.

② $V_{D_2} = V_{in} - V_B - R \cdot \frac{V_B}{2R} < 0$.

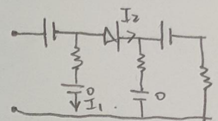
$V_{in} < \frac{3}{2}V_B$.

① & ②: $V_{in} < V_B$

We can see that D_1 should turn on before D_2.



3. D_2 off, D_1, D_3 ON.



D_2 off ⇒ $I_2 = 0$.

By KCL: $I_1 = I_{in}$.

$I_3 = -I_R$.

I_3 is same as before

$I_3 = \frac{V_B - 0}{2R}$. ⇒ $V_{out} = \frac{V_B}{2}$

Conditions & verify:

① $I_3 = \frac{V_B}{2R} > 0$ ⇒ D_3 is on, verified.

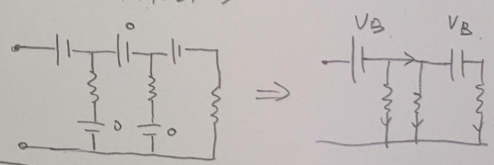
② $V_{D_2} = V_{in} - V_B - 0 - \frac{V_B}{2} < 0$

$V_{in} < \frac{3}{2}V_B$

③ $I_1 = \frac{V_{in} - V_B - 0}{R} > 0$ for $V_{in} > V_B$ verified.

①, ② & ③: $V_B < V_{in} < \frac{3}{2}V_B$

4. Last case: D_1, D_2, D_3 on.



$V_{out} = V_{in} - 2V_B$

① $I_1 = \frac{V_{in} - V_B}{R} = I_3 > 0$ ⇒ $V_{in} > V_B$

② $I_2 = \frac{V_{in} - V_B}{R} \quad \frac{V_{in} - 2V_B}{R} > 0$. ⇒ $V_{in} > \frac{3}{2}V_B$

① & ②: $V_{in} > \frac{3}{2}V_B$

please see next page ⟶

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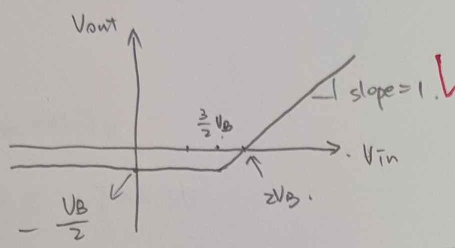
Name(last, first): Xie, Donlin

Name: [redacted] Student ID: [redacted]

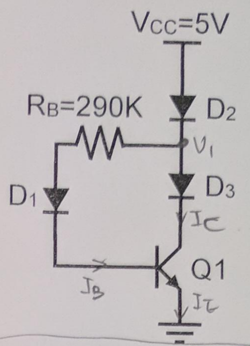
Sum up case 2,3,4:

$$\begin{cases} V_{out} = -\frac{V_B}{2}, & V_{in} < \frac{3}{2} V_B. \quad \Rightarrow \text{case 2,3 together} \\ V_{out} = V_{in} - 2V_B, & V_{in} \geq \frac{3}{2} V_B. \quad \Rightarrow \text{case 4.} \end{cases}$$



Name: [redacted] **Student ID:** [redacted]

3- Determine the terminal currents and the region of operation in this transistor circuit. Use a piecewise linear model for the diodes and assume V_{Don}=0.7V. In forward active mode β_F=100, V_{BEon}=0.7V, V_{CEsat}=0.2V, and in reverse active mode β_R=3, V_{BCon}=0.7V, V_{ECsat}=0.2V.
(25 points)



Assume Q_1 active, D_1, D_2, D_3 are on:

$V_E = 0$ V

$V_B = 0 + V_{BEon} = 0.7$ V

$V_1 = V_{CC} - V_{D2} = 5 - 0.7 = 4.3$ V

$I_B = \frac{V_1 - V_{D1} - V_B}{R_B} = \frac{4.3 - 0.7 - 0.7}{290k}$

$= \frac{2.9}{290k}$

$= 10 \mu A$ ✓

Since $I_B > 0$: BE Junction forward biased. D_1 indeed on. ✓ — verify

$I_C = \beta_F \cdot I_B = 100 \cdot 10\mu A = 1mA$

$I_E = I_B + I_C = 1.01$ mA

Since $I_C = I_{D3} > 0$, D_3 indeed on. $I_E = I_{D2} > 0$, D_2 indeed on. — verify

$V_C = V_{CC} - V_{D2} - V_{D3}$

$= 5 - 0.7 - 0.7 = 3.6$ V

$\therefore V_{CE} = V_C - V_E = 3.6 - 0 = 3.6$ ✓

$\because V_{CEsat} = 0.2$ V

$V_{CE} > V_{CE,sat}$, also $I_B > 0$ ✓ $\Rightarrow$ Q_1 is indeed in active mode — verify

$I_B = 10 \mu A$

$I_C = 1 mA$ ✓

$I_E = 1.01 mA$ ✓

$V_E = 0$ V ✓

$V_B = 0.7$ V

$V_C = 3.6$ V ✓

$V_{BE} = 0.7$ V ✓

$V_{CE} = 3.6$ V ✓

terminal currents & region of operation.