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

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~~	A semiconductor becomes more conductive as the temperatures rises above the room temperature.

(10 points)

forward bias No
reverse bias Yes

$T\uparrow$ $\frac{KT}{q}\uparrow$ $V_T\uparrow$ $\frac{V_D}{V_T}\downarrow$

Si 14
P 15

$I_D = I_S(\exp\frac{V_D}{V_T} - 1)$

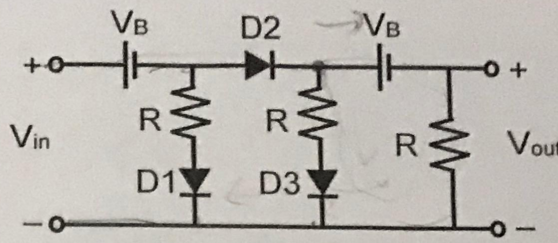
$I_D = I_S e^{\frac{V_D}{V_T}}$

$V_T = \frac{KT}{q}$

$K\uparrow$ $V_T\uparrow$

$I_S =$

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)

for D_1 to turn on: $V_{in} - V_B > 0$.

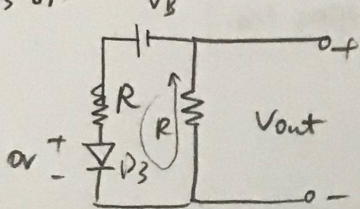
.. D_2 . . . . . . : $V_{in} - V_B - V_B > 0$ (−1)

.. D_3 - - - ; because of V_B ✓ D_3 always on. Vin @ $-\infty$, V_B enables D_3 ON; as V_{in} ↑ V_{in} enables D_3 ON

start from $-\infty = V_{in}$

D_1, D_2 off. D_3 ON

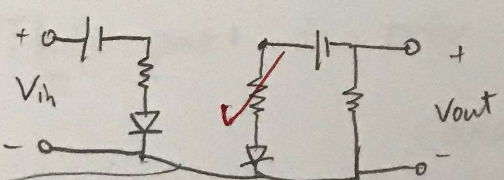
ckt ⇒

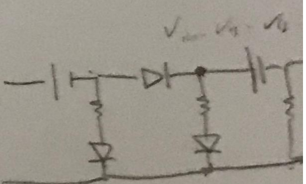


$V_{out} = -\frac{V_B}{2R} \cdot R = \checkmark -\frac{V_B}{2}$

state change @ $V_{in} \geq V_B$ → D_1 ON, D_3 remains on.

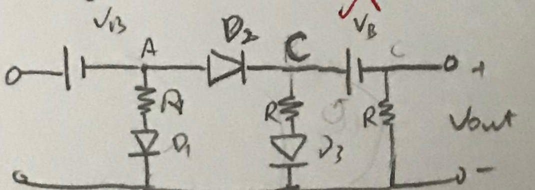
ckt →



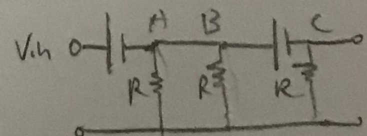


→ this is like common grounding 2 parts of ckt $V_{out} = \checkmark -\frac{V_B}{2}$

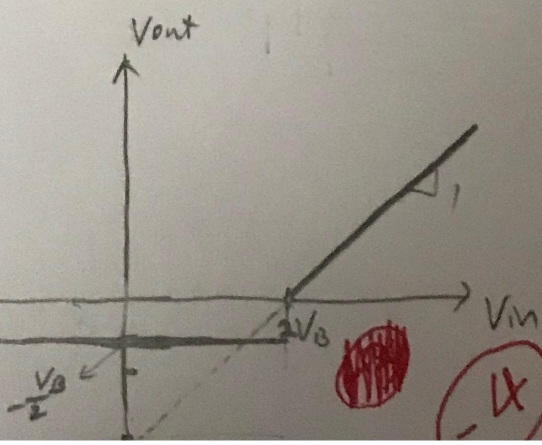
state change 2 @ $V_{in} \geq$ ~~2~~ V_B (−2) D_1, D_2, D_3 all on



⇒



$V_A = V_{in} - V_B$ $V_C = V_{in} - V_B$ $V_{out} = V_C - V_B$ ⇒ $V_{out} = V_{in} \checkmark - 2V_B$



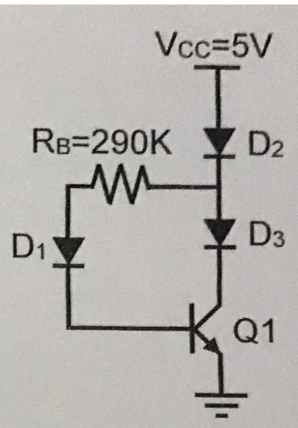
(−4)

in sum:

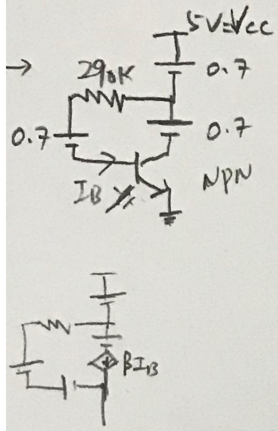
- for $V_{in} < 2V_B$
  $V_{out} = -\frac{V_B}{2}$
- for $V_{in} \geq 2V_B$
  $V_{out} = V_{in}$

$I_{D3} > 0$? (−5)

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 mode (forward)
(D_1, D_2, D_3 all on)



KVL @ Base:

$5 = 0.7 + I_B \times 290k + 0.7 - 0.7 = 0.$

$I_B = \frac{2.9}{290k} = 10^{-5}$ A $I_B > 0$ ☑

$\beta_F = 100 \rightarrow I_C = \beta I_B = 10^{-3}$ A

$I_E = (\beta+1) I_B = 1.01$ mA (1.01×10^{-3})

V_E is grounded $\Rightarrow V_E = 0$

$V_C = 5 - 0.7 - 0.7 = 3.6$ V

$V_{CE} = 3.6V > V_{CEsat}$ (0.2V) ☑

$\Rightarrow Q_1$ active

Now we need to verify D_1, D_2, D_3 diodes.

$I_{D2} = I_B + I_C = I_E = 1.01 \times 10^{-3}$ A $> 0 \Rightarrow D_2$ ON ☑

$I_{D1} = I_B = 10^{-5}$ A $> 0 \Rightarrow D_1$ ON ☑

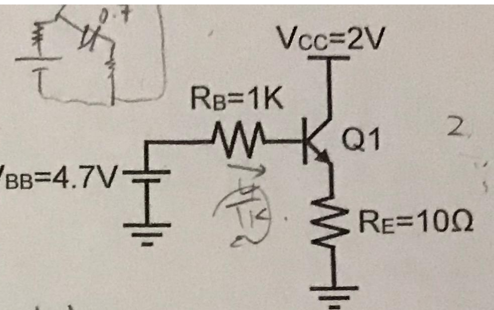
$I_{D3} = I_C = 10^{-3}$ A $> 0 \Rightarrow D_3$ ON ☑

all assumption right

$$\Rightarrow \begin{cases} I_B = 10^{-5} \text{ A} \\ I_C = 10^{-3} \text{ A} \\ I_E = 1.01 \times 10^{-3} \text{ A} \end{cases}$$

Q is in forward active region

4- Determine the terminal currents and the region of operation in this transistor circuit. In forward active mode β_F=99, V_{BEon}=0.7V, V_{CEsat}=0.2V, and in reverse active mode β_R=3, V_{BCon}=0.7V, V_{ECsat}=0.2V.



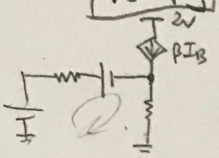
(25 points)

guess.

By observation : $V_{BB} > V_{cc}$. 2. forward bias

⇒ 2 independent diodes.

[Verify]: assume forward active



KVL @ base : $I_B = \frac{4.7 - 0.7}{1010} > 0$. $\beta_F = 99$

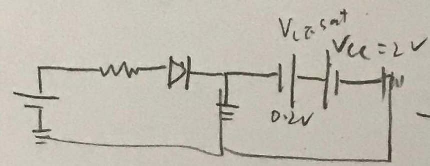
$I_E = 100 \times \frac{4}{1010} \approx 0.4A$

$V_E \approx 0.4 \times 10 = 4V > V_{cc}$ ⇒ $V_{CE} < 0$

$V_{CE} < V_{CEsat}$

$I_B > 0$ ⇒ Saturation

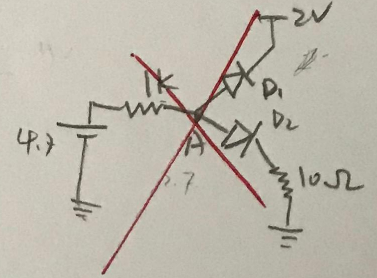
ckt ⇒



→ this ckt has no I_c

⇒ 2 independent diodes ⇒ assumption is correct ☑

ckt ⇒



if D_1, D_2 ON:

$V_A = 2.7$

$I_B = \frac{4.7 - 2.7}{1k}$ $I_E = \frac{2.7 - 0.7}{10}$

$I_B < I_E$ ⇒ impossible at th

if D_1, D_2 off $V_A = 4.7 > 0.7$ ⇒ also wrong assumption

if D_1 ON, D_2 off ⇒ $V_A = 2.7V > 0.7V$ ⇒ wrong again

(−15)

⇒ D_1 off, D_2 ON ⇒ $I = \frac{4.7 - 0.7}{1010} = \frac{4}{1010} A$, $I > 0$ ☑

$V_A = \frac{4}{1010} \times 10 + 0.7 = \frac{4}{101} + 0.7 \approx 0.74V < (2 + 0.7)V$ D_1 of

⇒ 2 independent diodes. "I_B" = "I_E" = $I = \frac{2}{505}$ A ?

BC diode off

BE diode on