IE Quiz 1 Solution

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Q1. In the given circuit in Fig. 1, for the transistor Q, base to emitter drop (VBE ON) is 0.7 V, Vce(sat) = 0.2 V and zener breakdown voltage is given to be 4.8 V.

a.) Calculate the value for the dc current gain β for Q? Take Rc = 330 Ohm. [10 Marks]

b.) What is the range of Rc for which Q1 will remain in active region. [15 Marks]

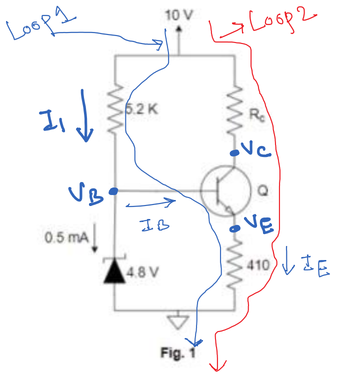


Fig. 1

Solution (a.) Since 0.5mA current is flowing in the Zener, hence it is in breakdown.

$V_B = 4.8V$

Applying KVL in loop 1

$-10 + (10 - V_B) + V_{BEON} + I_E \times 410 = 0$

$\Rightarrow \cancel{-10} + (\cancel{10}-4.8) + 0.7 + 410 I_E = 0$

$\Rightarrow I_E = \frac{4.8-0.7}{410} = \frac{4.1}{410} = \frac{41}{410} \times 10^{-1} = 10^{-2}$

$\therefore I_E = 10\,mA$ ——— ①

I_1 in the above fig $= \frac{10-4.8}{5.2K} = \frac{5.2}{5.2} \times 10^{-3} = 1\,mA$

$\therefore I_B = I_1 - 0.5 = 0.5mA$

Now, $I_E = (\beta+1) I_B \therefore \beta + 1 = \frac{I_E}{I_B} = \frac{10\,mA}{0.5mA} = 20$

$\therefore \beta = 19$

Since, KVL in loop 1 was applied by assuming Q to be in active region.

$\therefore$ Checking the terminal voltages of Q:

$V_E = 410 \times I_E = 4.1V$

$I_c = \beta \times I_B = 19 \times 0.5mA = 9.5mA$

$V_C = 10 - I_C \times R_C = 10 - 9.5m \times 330\Omega$

$= 10 - 3.135 = 6.865$

$\therefore V_{CB} = 6.865 - 4.8 = 2.065 \rightarrow$ Reverse Biasing of CB jn

$V_{BE} = 0.7 \longrightarrow$ EB jn is in Forward bias

Hence, our assumption was correct and Q is operating in active region with $\boxed{\beta = 19}$

Solution (b)

Applying KVL in loop2 (as indicated in the figure)

$-10 + I_C \times R_C + V_{CE} + I_E \times 410 = 0$ ——— ①

Since, Current through the zener is maintained at 0.5mA (as per question)

$I_B = 0.5mA$ (for the transistor to work in active region)

$\therefore I_C = 9.5mA$

$I_E = 10 mA$

∴ Putting all these values in (1)

$$-10 + 9.5m \times R_C + V_{CE} + 9.5m \times 410 = 0$$

$$+9.5m R_C + V_{CE} = 10 - 3.895 = 6.105$$

$$V_{CE} = 6.105 - 9.5 \times 10^{-3} R_C \quad \text{———} \quad (2)$$

Now for the Q to remain in active region

$$V_{CE} > 0.2V$$

$$\therefore \quad 6.105 - 9.5 \times 10^{-3} R_C > 0.2V$$

$$9.5 \times 10^{-3} R_C < 6.105 - 0.2 = 5.905$$

$$\therefore \quad R_C < \frac{5.905}{9.5} \times 10^3 \approx 0.62158 \times 10^3 \Omega$$

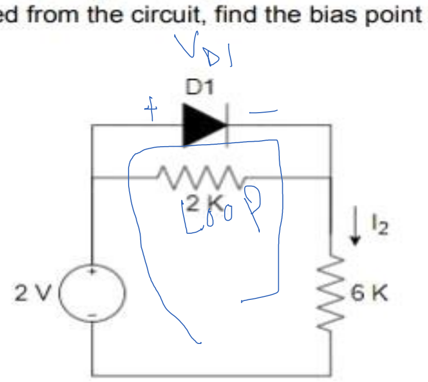
$$\therefore \quad R_C < 621.58 \Omega$$

∴ $\boxed{\text{Range of } R_C \text{ will be } [0, 621.58\Omega).}$

Q2. In the circuit shown in Fig. 2, diode is ideal with a cut-in voltage of 0.7 V.

a.) Find the magnitude of current I2. [10 Marks]

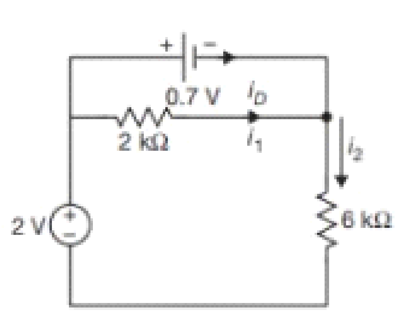
b.) If 2 K ohm arm is removed from the circuit, find the bias point for D1. [15 Marks]



Solution(a)

Fig. 2

We begin by converting the ideal diode to a voltage drop.



Let $i_2 = i_1 + i_D$. Applying KVL,

$$i_2 = \frac{2 - 0.7}{6} = 0.216mA$$

$$i_1 = \frac{0.7}{2} = 0.35mA$$

$$i_2 < i_1$$

$$\therefore i_D = -0.134$$

The diode is forward biased and it requires poitive current to flow through it for conduction, but i_D is negetive, so the diode is in OFF state.

$$\therefore i_2 = \frac{2}{2+6} = 0.25mA$$

Solution (b) If 2K arm is removed then applying KVL in the loop

$$-2V + V_{D1} + 6K \cdot I_{D1} = 0 \quad (\text{Since, } I_{D1} = \text{diode current} = I_2)$$

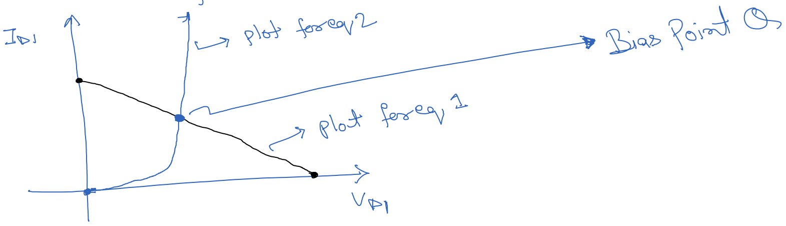
$$\therefore \quad 6K I_{D1} + V_{D1} = 2 \longrightarrow (1)$$

Now the relation between V_{D1} and I_{D1} is known to us as

$$I_{D1} = I_0\left(e^{qV_{D1}/\eta V_T} - 1\right) \longrightarrow (2) \quad \{\text{Take } \eta = 1\}$$

where, I_0 = Reverse saturation current

Plotting I_{D1} vs V_{D1} for both (1) and (2)



From the above figure by solving eqn (1) & (2) we can get the exact bias point (indicated in the plot by Q) for diode D1.

However, if we assume that diode drop will be approximately 0.7V then

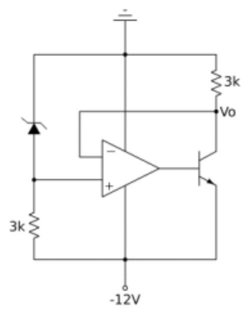
$$I_{D1} = \frac{2-0.7}{6K} = \frac{1.3}{6K} \approx 0.217\, mA$$

$\therefore$ (0.217 mA, 0.7V) will be an approximate estimation of the bias point for D1.

Q3. In the circuit shown in Fig. 3, breakdown voltage of the zener is 5V, β of the NPN transistor is 100. Assume that V_{BE} (ON) is 0.7V

a.) Find the current and voltage at each terminal of the transistor. [15 marks]

b.) Can you make an NPN-BJT by connecting two PN junctions together from their P-terminal and using the N-terminals as Collector and Emitter (Refer Fig. 4). Give a detailed explanation. [10 Marks]



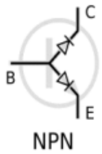
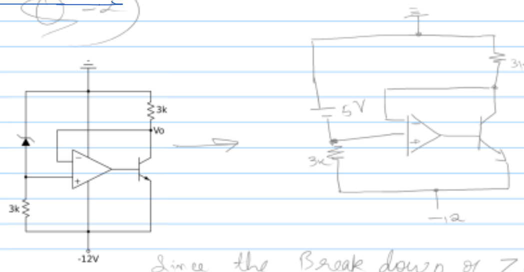


Fig. 4

Solution(a)



Since the Break down of Zener Diode is 5V, it will act like an Ideal Voltage Source in this case &

$V_+ = -5V$

$\Rightarrow V_- = -5V$ (Virtual short)

$\Rightarrow I_C = \frac{5}{3K} = 1.66mA$ $\quad V_C = -5V$

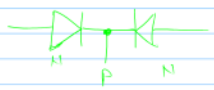
$\Rightarrow I_B = \frac{I_C}{\beta} = \frac{1.66mA}{100} = 16.66\mu A$

$\Rightarrow I_E = I_B + I_C = 1.6766mA$

$V_B = -11.3V$ $\quad V_E = -12V$

Solution(b)

B) A BJT can not be formed by



The N-Side of both the Diodes is at same Doping Concentration

The base Width of this design can not be ensured to be ultra-thin. The carriers Concentration profile is not guaranteed to be linearly decreasing in p-region Thus there will not be a proper diffusion of n-type carriers from N to N. Thus the design will NOT work

Q4. For the circuit shown in Fig. 5, diode is ideal with a negligible cut-in voltage.

a.) Find the relation between Vo and Vi. Note that VI can be both +ve and -ve. [15 Marks]

b.) Which circuit you have studied so far mimics the above circuit's behavior. Is there any advantage of the below circuit over the other circuit? [10 Marks]

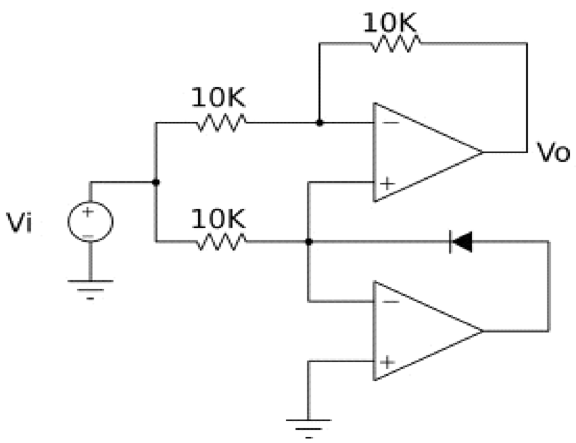
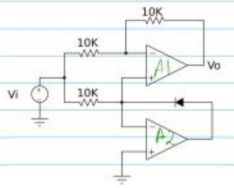


Fig. 5

Solution (a.)



a) This question has to be solved in two steps :

i) For the case when $V_i > 0$

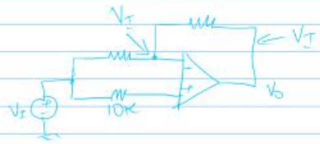
ii) $V_i < 0$

i) When $V_i > 0$:

Virtual short Concept can not be applied in the op-amp for this case as the Diode will be in Reverse Bias.

Thus there will be no -ve feedback from Diode to the op-amp.

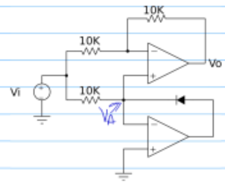
So the voltage at non-inverting terminal will not be 0 and since the diode is Reverse Biased; we can open it



$\Rightarrow V_o = V_I$

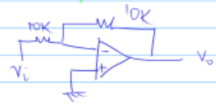
$\Rightarrow$ for $V_I > 0$: $V_o = V_I$

Case 2 : $V_I < 0$:



When $V_I < 0$; the Diode can be forward Biased So the diode will act as a wire. So the op-amp is Virtual Short will be valid in this case.

$\Rightarrow V_A = 0V$ $\rightarrow$



$\Rightarrow V_o = -V_i$

Solution b $\Rightarrow$ for $V_i < 0 \rightarrow V_o = -V_I$

$\rightarrow$ Combining : $V_o = |V_I|$

B) This acts as a Rectifier. The potential drop across the diode does not appear in the output of this circuit. Thus this circuit can be used for rectifying Low Voltage signals!