3EJ4 LAB ONE

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Questions for Part 1(NPN-BJT 2N304):

According to the requirement, I got I_C = 1.02*10^-3A and V_{CE} = 1.898V from my table, Steps 1.2-1.4.

(VE = -1.5V, VCC = 0.5V)

Q1.

(1) V_{BEon} = 0.621v I_B = 8.79 μA.

(2) Since I_C = 1.02*10^-3 A

β = I_C/I_B = 1.02*10^-3 A/8.79 μA = 117

(3) |VA| = 1000V

(4) r_o = 976 KΩ

(5) g_m = 41 mS

(6) r_π = 2.845 KΩ

Q2.

According to the requirement, I got I_C = 1.59*10^-3 A and V_{CE} = 3.3408 V from my table, Steps 1.8. (NPN-BJT 2N304)

(1) I_C = 1.59mA

(2) V_{BEon} = 0.653v I_B = 8.47μA

(3) Since I_C = 1.59*10^-3A

β = I_C/I_B = 1.59*10^-3A/8.47 μA = 187.72

(4) |VA| = 75 V.

(5) r_o = 47.1kohm

(6) g_m = 63.7mS

(7) r_π = 2.952 KΩ

Q3.

Questions for Part 2(PNP-BJT 2N306):

According to the requirement, I got I_C = 1.03*10^-3 A and V_{EC} = 1.90 V from my table, Steps 2.2-2.4.

(VE = -1.5V, VCC = 0.5V)

(1) V_{BEon} = 0.660v I_B = 8.40 μA.

(2) Since I_C = 1.03*10^-3 A

β = I_C/I_B = 1.03*10^-3 A/8.40 μA = 122.62

(3) |VA| = 143 V.

(4) r_o = 139 KΩ

(5) g_m = 41.2 mS

(6) r_π = 2.976 KΩ

Q4.

According to the requirement, I got I_C = 1.82*10^-3 A and V_{EC} = 1.82 V from my table, Steps 1.8. (PNP-BJT 2N306)

(1) I_C = 1.82 mA

(2) V_{BEon} = 0.669v. I_B = 8.31μA.

(3) Since I_C = 1.82*10^-3 A

β = I_C/I_B = 1.82*10^-3 A/8.31μA = 219.01

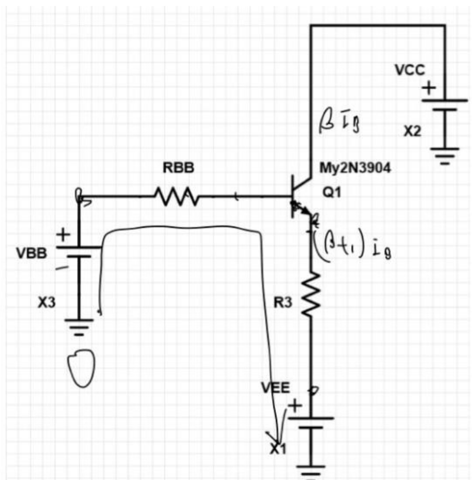
(4) |VA| = 28 V.

(5) r_o = 15.6 KΩ

(6) g_m = 72.8mS

(7) r_π = 3.008 KΩ

Q5.



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$$0 + V_{BB} - I_B \cdot R_{BB} - V_{BEon} - (\beta+1) I_B \cdot R_3 - V_{EE} = 0$$

$$-I_B \left(R_{BB} + (\beta+1) R_3\right) = V_{EE} - V_{BB} + V_{BEon}$$

$$I_B = \frac{-(V_{EE} - V_{BB} + V_{BEon})}{(R_{BB} + (\beta+1) R_3)}$$

Q6. Compared to the I_B expression obtained in Q5 with (1.3),

$$(1.3):\ I_B = \frac{V_{BB} - (V_{EE} + V_{BEon})}{R_{BB}} \qquad (Q5):\ I_B = \frac{-(V_{EE} - V_{BB} + V_{BEon})}{(R_{BB} + (\beta+1)R_3)}$$

The difference is that the equation derived in Q5 has an additional $(\beta+1)R_3$ in the denominator.

If ΔV_{EE} is applied,

* using (1.3),

$$\Delta I_{B1} = I_B' - I_B = \frac{V_{BB} - (V_{EE} + \Delta V_{EE} + V_{BEon})}{R_{BB}} - \frac{V_{BB} - (V_{EE} + V_{BEon})}{R_{BB}}$$

$$= \frac{-\Delta V_{EE}}{R_{BB}}$$

* using the equation in Q5,

$$\Delta I_{B2} = I_B' - I_B = \frac{V_{BB} - (V_{EE} + \Delta V_{EE} + V_{BEon})}{R_{BB} + (\beta+1)R_3} - \frac{V_{BB} - (V_{EE} + V_{BEon})}{R_{BB} + (\beta+1)R_3} = \frac{-\Delta V_{EE}}{R_{BB} + (\beta+1)R_3}$$

$$|\Delta I_{B2}| - |\Delta I_{B1}| = \Delta V_{EE}\left(\frac{1}{R_{BB} + (\beta+1)R_3} - \frac{1}{R_{BB}}\right) = \Delta V_{EE} \cdot \frac{-(\beta+1)R_3}{R_{BB}(R_{BB} + (\beta+1)R_3)} < 0$$

Hence $|\Delta I_{B2}| < |\Delta I_{B1}|$ $\therefore$ R_3 reduces ΔI_B when there is a ΔV_{EE} applied.

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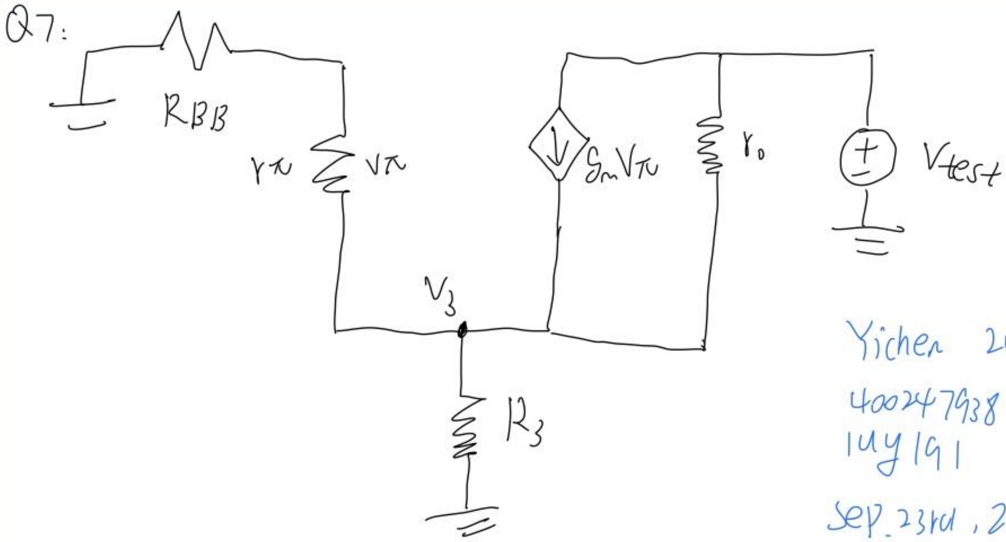
Q7:



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$$V_3 = [(R_{BB} + r_\pi) // R_3] \cdot I_{test}$$

$$I_{test} = g_m V_\pi + \frac{V_{test} - V_3}{r_0}$$

$$V_\pi = -[(R_{BB} + r_\pi) // R_3] \cdot I_{test} \cdot \frac{r_\pi}{r_\pi + R_{BB}}$$

$$I_{test} = -g_m [(R_{BB} + r_\pi) // R_3] \cdot I_{test} \cdot \frac{r_\pi}{r_\pi + R_{BB}} + \frac{V_{test} - [(R_{BB} + r_\pi)//R_3] \cdot I_{test}}{r_o}$$

$$I_{test} = -g_m [(R_{BB} + r_\pi)//R_3] \cdot I_{test} \cdot \frac{r_\pi}{r_\pi + R_{BB}} + \frac{V_{test}}{V_0} - \frac{[(R_{BB} + r_\pi)//R_3] \cdot I_{test}}{r_o}$$

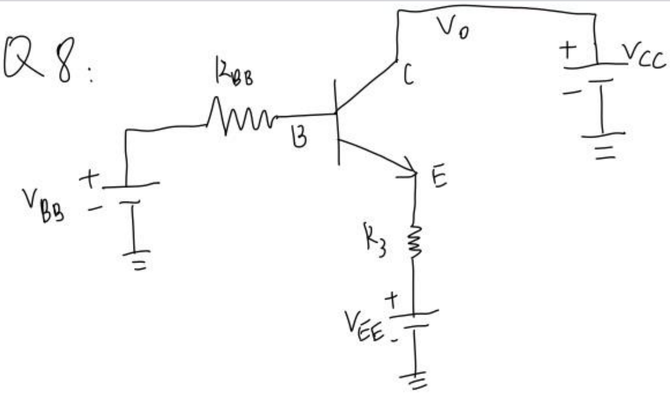
$$I_{test} + g_m [(R_{BB} + r_\pi)//R_3] \cdot I_{test} \cdot \frac{r_\pi}{r_\pi + R_{BB}} + \frac{[R_{BB} + r_\pi)//R_3] \cdot I_{test}}{r_o} = \frac{V_{test}}{r_o}$$

$$I_{test} \left\{ 1 + g_m [(R_{BB} + r_\pi)//R_3] \cdot \left[\frac{r_\pi}{r_\pi + R_{BB}}\right] + \frac{[(R_{BB} + r_\pi)//R_3]}{r_o} \right\} = \frac{V_{test}}{r_o}$$

$$\therefore \frac{V_{test}}{I_{test}} = r_o + [(R_{BB} + r_\pi)//R_3] + g_m [(R_{BB} + r_\pi)//R_3] \cdot r_o \cdot \left[\frac{r_\pi}{r_\pi + R_{BB}}\right]$$

$$\therefore R_o = r_o + [R_3 // (R_B + r_\pi)] \left[1 + g_m r_o \left(\frac{r_\pi}{R_{BB} + r_\pi}\right)\right]$$

Q8:



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$\because V_o = V_{CC}$

$\because V_{o,min} = V_E + 0.3V$ (according to part 3/4),

$\therefore$ BJT works in active region

$V_{o,min} = V_E + 0.3V$

$= V_{EE} + V_3 + 0.3V$

$= V_{EE} + (\beta+1) I_B R_3 + 0.3V$

$= \boxed{V_{EE} + (\beta+1) R_3 \dfrac{V_{BB} - V_{EE} - V_{BE,on}}{R_{BB} + (\beta+1) R_3} + 0.3V}$

$\boxed{\therefore V_{o,min} = V_{EE} + I_E R_3 + 0.3V}$

Q9 $\because V_{EE} = -5V$, $I_o = 1mA = I_C$, $V_{o,min} = -1V$ $\beta = 117$ (from Q4)

$R_2 = 100k\Omega$, $V_{CE} = 0.3V$

$\because V_{o,min} = V_{EE} + I_E R_3 + 0.3V$

$\because \frac{I_C(\beta+1)}{\beta} = I_E$

$\therefore R_3 = \frac{V_3}{I_3} = \frac{V_{o,min} - V_{EE} - V_{CE}}{I_E} = \frac{V_{o,min} - V_{EE} - V_{CE}}{\frac{I_C(\beta+1)}{\beta}} = \frac{(-1V)-(-5V)-0.3}{\frac{1mA(117+1)}{117}}$

$\therefore R_3 = (-1-0.3+5)/(1\cdot\frac{118}{117})\ k\Omega = \boxed{3.669\ k\Omega}$

$\because R_{BB} = \frac{R_1R_2}{R_1+R_2}$, $V_{BB} = \frac{R_1}{R_1+R_2} V_{EE}$, $\therefore V_{BB} = R_{BB} \cdot \frac{V_{EE}}{R_2}$

$\because V_{o,min} = V_{EE} + (\beta+1)R_3 \frac{V_{BB} - V_{EE} - V_{BEon}}{R_{BB} + (\beta+1)R_3} + 0.3$

$\therefore \frac{V_{BB} - V_{EE} - V_{BEon}}{R_{BB} + (\beta+1)R_3} = \frac{V_{o,min} - V_{EE} - 0.3}{(\beta+1)R_3}$

$\frac{R_{BB} \cdot \frac{V_{EE}}{R_2} - V_{EE} - V_{BEon}}{R_{BB} + (\beta+1)R_3} = \frac{V_{o,min} - V_{EE} - 0.3}{(\beta+1)R_3}$

$\frac{R_{BB} \cdot \frac{-5}{100} + 5 - 0.621}{R_{BB} + 118 \times 3.669} = \frac{-1+5-0.3}{118 \times 3.669}$

$-\frac{1}{20} R_{BB} + 4.379 = 8.5462 \times 10^{-3} \cdot R_{BB} + 3.7$

$\therefore R_{BB} = 11.5977\ k\Omega$

$\because R_{BB} = \frac{R_1R_2}{R_1+R_2}$ $\therefore R_1 = \frac{1}{\frac{1}{R_{BB}} - \frac{1}{R_2}} = \frac{1}{\frac{1}{11.5977} - \frac{1}{100}} = \boxed{13.12\ k\Omega}$

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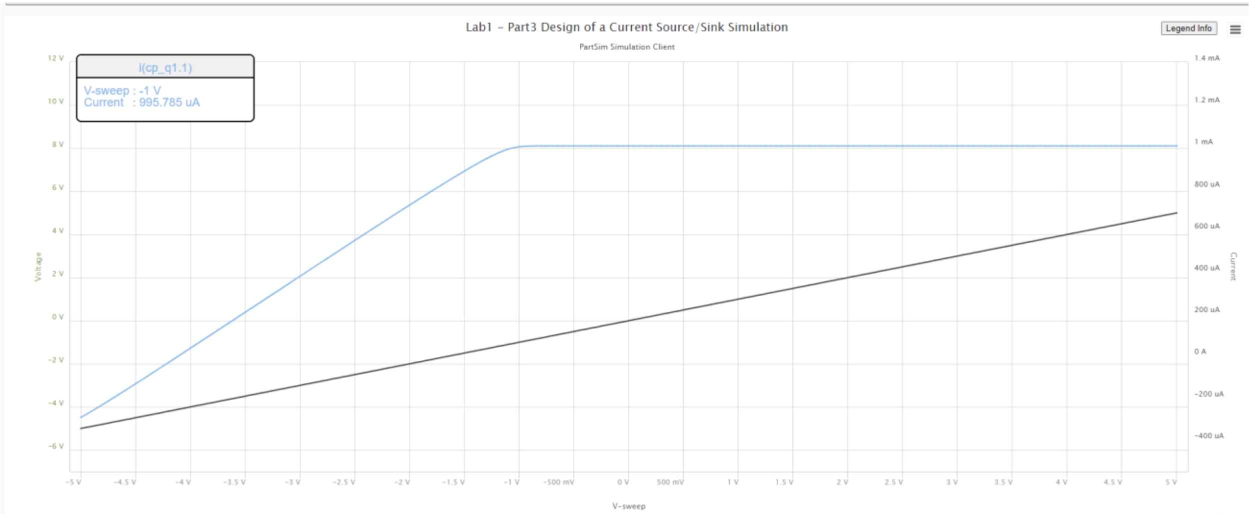
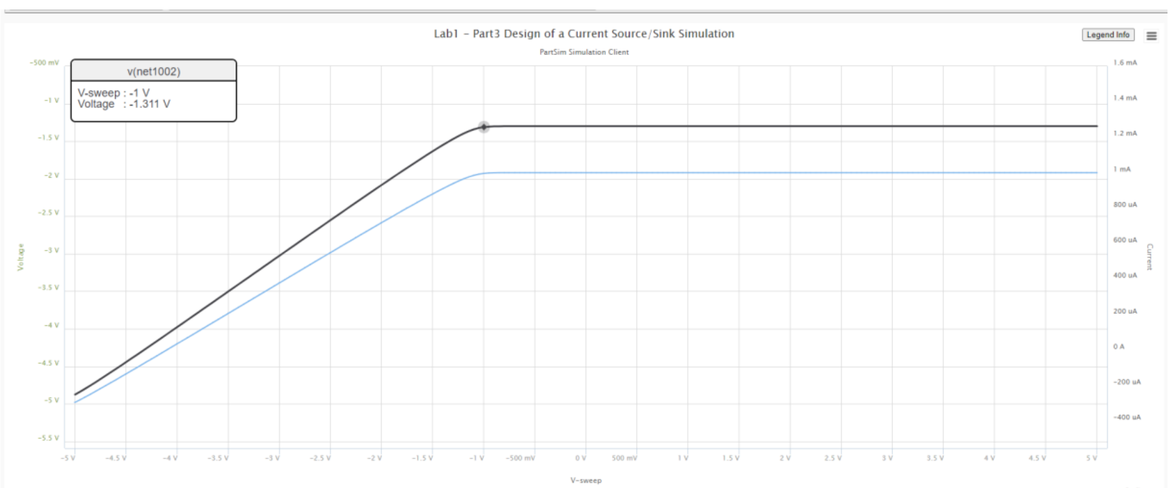


Q10



As the figure shown, the difference between V_C and V_E is -1V-(-1.311V) = 0.311V which is close to 0.3V as I_C turns into the active region. Hence, this result determines that our assumption for $|V_{CE}|$>=0.3V for Q1 to work in the active region is correct.