Electronic Devices & Circuits II - EE 3EJ4
Lab #1

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2023 - 09 - 29

Questions for Part 1

Q1. (7 Points)

V+ (VCC)	V- (VE)	V(Q1C) (Volt)	V(Q1B) (Volt)	VCE (Volt)	VBEon (Volt)	RC (ohm)	RB (ohm)	IC (A)	IB (A)	β = IC/IB	|VA| (V)	ro=VA/IC	gm = IC/25mV	rπ = 25mV/IB
0.5	-1.5	0.397558296	-0.87868933	1.898	0.621	100	1.00E+05	1.02E-03	8.79E-06	117	1000	9.76E+05	4.10E-02	2845

(1) $V_{BEon} = 0.621V$ and $I_B = 8.79 \times 10^{-6}A = 8.79\mu A$

(2) $\beta = 117$

(3) $\left|V_a\right| = 1000V$

(4) $r_0 = 9.76 \times 10^5\Omega = 976k\Omega$

(5) $g_m = 4.10 \times 10^{-2}\frac{A}{mV} = 41mS$

(6) $r_\pi = 2845\frac{mV}{A} = 2.845k\Omega$

Q2. (8 Points)

V+ (VCC)	V- (VE)	Channel 1 (VC)	Channel 2 (VB)	VCE (Volt)	VBEon (Volt)	RC (ohm)	RB (ohm)	IC (A)	IB (A)	β = IC/IB	|VA| (V)	ro=VA/IC	gm = IC/25mV	rπ = 25mV/IB
0.5	-1.5	0.326	-0.825	1.826	0.675	100	1.00E+05	1.74E-03	8.25E-06	211	213	1.22E+05	6.96E-02	3030

(1) $I_c = 1.74mA$

(2) $V_{BEon} = 0.675V$ and $I_B = 8.25 \times 10^{-6}A = 8.25\mu A$

(3) $\beta = 211$

(4) $\left|V_a\right| = 213V$

(5) $r_0 = 1.22 \times 10^5\Omega = 122k\Omega$

(6) $g_m = 6.96 \times 10^{-2}\frac{A}{mV} = 69.6mS$

(7) $r_\pi = 3030\frac{mV}{A} = 3.03k\Omega$

Questions for Part 2

Q3. (7 Points)

V+ (VE)	V- (VCC)	V(Q1C) (Volt)	V(Q1B) (Volt)	VEC (Volt)	VEBon (Volt)	RC (ohm)	RB (ohm)	IC (A)	IB (A)	β = IC/IB	|VA| (V)	ro=VA/IC	gm = IC/25mV	rπ = 25mV/IB
1.5	-0.5	-0.397093315	0.839935339	1.90	0.660	100	1.00E+05	1.03E-03	8.40E-06	123	143	1.39E+05	4.12E-02	2976

(1) $V_{BEon} = 0.66V$ and $I_B = 8.40 \times 10^{-6}A = 8.40\mu A$

(2) $\beta = 123$

(3) $|V_a| = 143V$

(4) $r_0 = 1.39 \times 10^5\Omega = 139k\Omega$

(5) $g_m = 4.12 \times 10^{-2}\frac{A}{mV} = 41.2mS$

(6) $r_\pi = 2976\frac{mV}{A} = 2.976k\Omega$

Q4. (8 Points)

V+ (VE)	V- (VCC)	Channel 1 (VC)	Channel 2 (VB)	VEC (Volt)	VEBon (Volt)	RC (ohm)	RB (ohm)	IC (A)	IB (A)	β = IC/IB	|VA| (V)	ro=VA/IC	gm = IC/25mV	rπ = 25mV/IB
1.5	-0.5	-0.3342	0.831	1.83	0.669	100	1.00E+05	1.66E-03	8.31E-06	200	32	1.93E+04	6.63E-02	3008

(1) $I_c = 1.66mA$

(2) $V_{BEon} = 0.669V$ and $I_B = 8.31 \times 10^{-6}A = 8.31\mu A$

(3) $\beta = 200$

(4) $|V_a| = 210V$

(5) $r_0 = 1.93 \times 10^4\Omega = 19.3k\Omega$

(6) $g_m = 6.63 \times 10^{-2}\frac{A}{mV} = 66.3mS$

(7) $r_\pi = 3008\frac{mV}{A} = 3.008\Omega$

Questions for Part 3

Q5. (10 Points)

Applying KVL from Base to Emitter yeilds:

$$V_{BB} - R_{BB} I_B - V_{BEon} - I_E R_3 - V_{EE} = 0$$

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

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

Aside

$$i_c = \beta i_B = \alpha i_e$$

$$\beta i_b = \alpha i_e$$

$$\beta i_b = \frac{\beta}{\beta+1} i_e$$

$$i_e = (\beta+1) i_b$$

Q6. (10 Points)

Using equation (3): let $\Delta VEE = VEE + \Delta VEE$

$$IB + \Delta IB_1 = \frac{VBB - (VEE + \Delta VEE) + VBEon}{RBB}$$

$$\boxed{\Delta IB1 = \frac{VBB - (VEE + \Delta VEE) + VBEon}{RBB}} \quad -(1)$$

Using equation Q5: let $\Delta VEE = VEE + \Delta VEE$

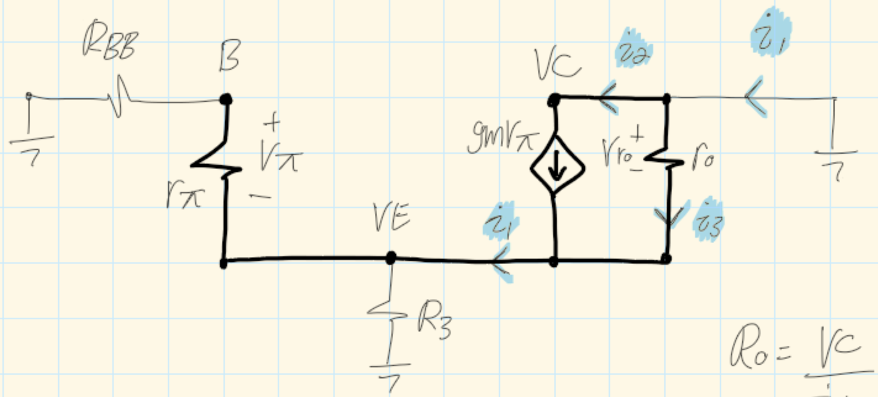
$$IB + \Delta IB2 = \frac{VBB - (VEE + \Delta VEE) + VBEon}{RBB + (\beta+1)R3}$$

$$\boxed{\Delta IB2 = \frac{VBB - (VEE + \Delta VEE) + VBEon}{RBB + (\beta+1)R3}} \quad -(2)$$

The main difference between these 2 equations is that in equation (3) we do not see the presence of R_3. This is because it was taken to be 0, based on V_{BEon} as obtained in the previous section. In ***Q5*** we do not consider $R_3 = 0$ and thus we get the term, $(\beta + 1)R_3$

Since β is always a positive value, and the resistance, R_3 is also always positive, then we can conclude that the term $(\beta + 1)R_3$ will be an overall positive value. This means that equations *(1)* and *(2)* have the same numerator, but *(2)* will always have a larger denominator than *(1)*. This means that for all parameters, $\Delta I_{B2} < \Delta I_{B1}$. This confirms the idea that the emitter resistor, R_3, reduces the change in I_B

Q7. (15 Points)



$$R_o = \frac{V_C}{i_1}$$

$i_2 = g_m V_\pi$

$i_1 = i_2 + i_3 \Rightarrow i_3 = i_1 - i_2 = i_1 - g_m V_\pi$

$V_{ro} = r_o \cdot i_3 = (r_o)(i_1 - g_m V_\pi)$

$V_E = (i_1)[(R_{BB} + r_\pi) \| R_3]$

$V_\pi = -V_E \cdot \dfrac{r_\pi}{R_{BB} + r_\pi}$

$V_C = V_E + V_{ro}$

$V_C = \big((i_1)[(R_{BB} + r_\pi) \| R_3]\big) + r_o(i_1 - g_m V_\pi)$

Aside: $\boxed{\text{let } x \text{ represent } (R_{BB} + r_\pi) \| R_3}$

$V_C = (x)(i_1) + r_o(i_1 - g_m V_\pi)$

$V_C = x i_1 + r_o i_1 + \dfrac{g_m V_E r_\pi}{R_{BB} + r_\pi} \cdot r_o$

$V_C = x i_1 + r_o i_1 + \dfrac{g_m r_\pi}{R_{BB} + r_\pi} \cdot x i_1 \cdot r_o$

$$\frac{V_C}{i_1} = x + r_o + \frac{g_m r_\pi}{R_{BB} + r_\pi} \cdot x \cdot r_o = R_o$$

$$R_o = r_o + [R_3 \| (R_{BB} + r_\pi)] + \frac{g_m r_\pi}{R_{BB} + r_\pi} \cdot [R_3 \| (R_{BB} + r_\pi)] \cdot r_o$$

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

Q8. (10 Points)

Since $R_3 \neq 0$, we now have to take into account a voltage drop across this resistor. Previously, we had the expression $V_{o, min} = V_E + 0.3V$, the resistor, R_3, has a voltage drop defined by $V_{R3} = I_e R_3$ and thus we can define a new expression for $V_{o, min}$, where $V_{o, min} = V_E + 0.3V + I_e R_3$

Q9. (15 Points)

$V_{EE} = -5V$ $\quad R_3 = ?$ $\quad$ from Q1, $\beta = 117$ $\quad i_c = \beta i_b = \alpha i_e$

$I_o = 1mA = I_C$ $\quad R_2 = 100k$ $\quad V_{CE} = 0.3V$ $\quad \beta i_b = \alpha i_e$

$V_{o,min} = -2V$ $\quad R_1 = ?$

$V_{o,min} = V_{EE} + I_E R_3 + 0.3V \rightarrow I_e = \frac{\beta+1}{\beta} I_C$

$$R_3 = \frac{V_3}{I_3} = \frac{V_{o,min} - V_{EE} - V_{CE}}{I_E} = \frac{V_{o,min} - V_{EE} - V_{CE}}{\frac{\beta+1}{\beta} \cdot I_C} = \frac{(-2)-(-5)-0.3}{\left(\frac{118}{117}\right)(1mA)} = \boxed{2.67\,k\Omega}$$

from the given Circuits: $V_{BB} = \frac{R_1}{R_1+R_2} V_{EE}$, $R_{BB} = R_1 \| R_2$

$$I_B R_{BB} + V_B = \frac{R_1}{R_1+R_2} V_{EE}$$

$$I_B \cdot \frac{R_1 R_2}{R_1+R_2} + V_B = \frac{R_1}{R_1+R_2} V_{EE}$$

$$\frac{I_C}{\beta} \cdot \frac{100R_1}{100+R_1} + V_B = \frac{R_1}{100+R_1}(-5) \Rightarrow$$

Aside

$$V_B = V_{EE} + I_E R_3 + V_{BEon}$$

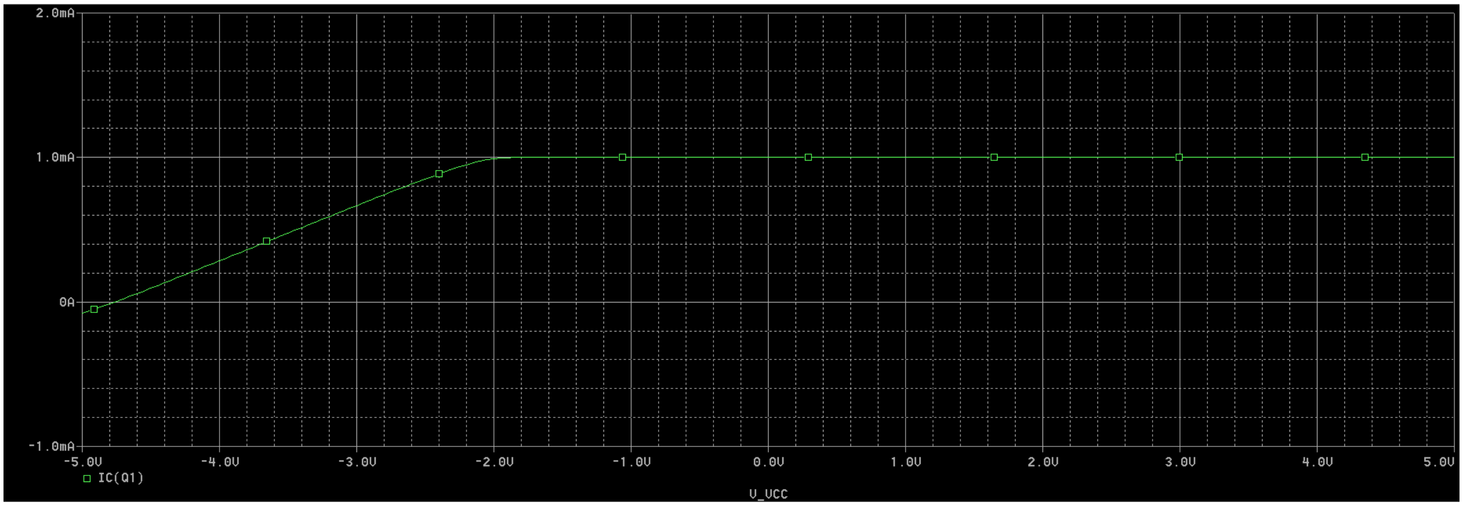
$$V_B = -5 + \left(\frac{118}{117}\right)(2.67) + 0.621$$

$$V_B = -1.686V$$

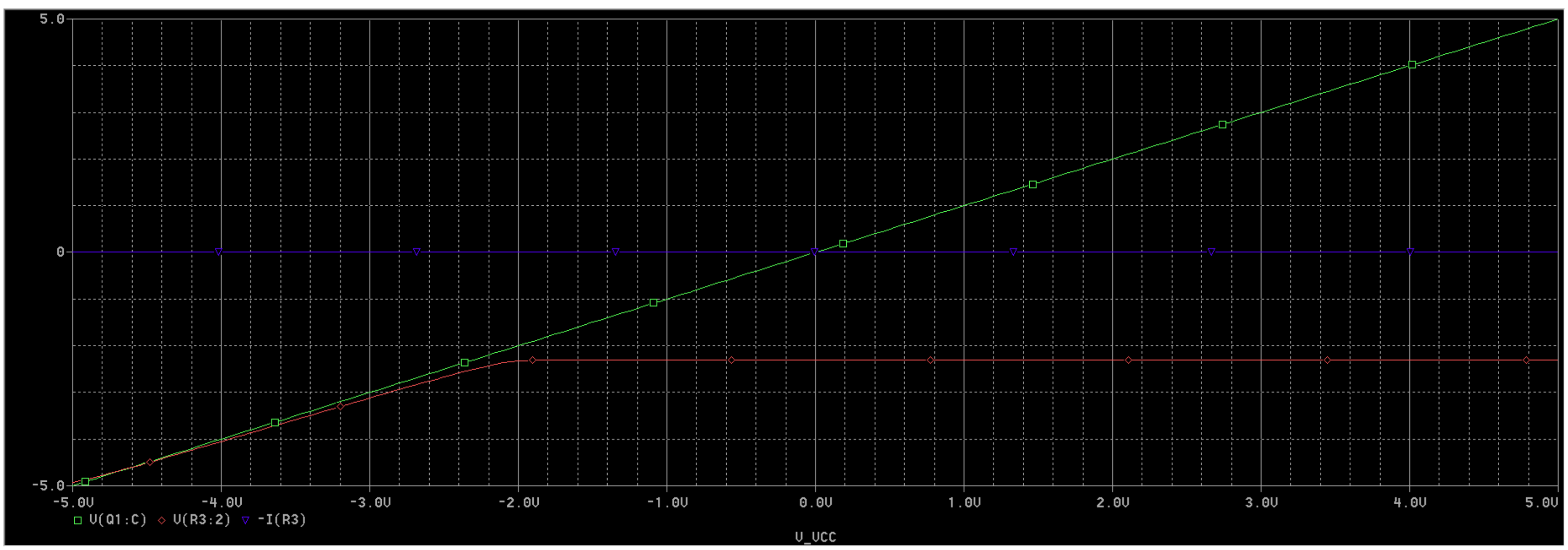
$$\frac{1}{117} \cdot \frac{100R_1}{100+R_1} - 1.686 = \frac{R_1}{100+R_1}(-5)$$

$$\boxed{R_1 = 40.4\,k\Omega}$$

The plot of I_o vs V_{cc} can be found below



Q10. (10 Points)



Above is the plot of I_C $(Blue)$, V_{CC} $(Green)$ & V_E (Red)

By generating a plot of V_{cc} vs V_E we can determine the $|V_{CE}|$. As can be seen from the graph above, $|V_{CE}| = V_{cc} - V_E = (-\ 2V)\ -\ (-\ 2.3V)\ =\ 0.3V$ and thus we can verify the operating condition that $|V_{CE}| \geq\ 0.3V$

The circuit used to simulate the above can be found below –