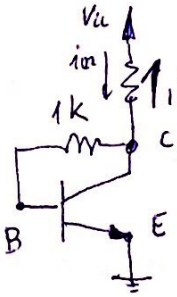
(74) $V_\gamma = V_{BE} = 0{,}6V$ $V_{BES} = 0{,}6V$ $V_{CES} = 0{,}2V$ $\beta = 100$ $V_{CC} = 12V$ $R_1 = 10k\Omega$ $R_2 = 1k\Omega$

u n. Q - OFF

$i_B = v_C = i_C = 0$ $v_E = 0$ $v_{BE} = 0 < V_\gamma \Rightarrow$ Q OFF (T)

$v_B = 0$ $v_C = V_{CC}$

(75)



$i_C + i_B = i_E$

$V_{CC} - i_{R2} \cdot R_2 - i_B \cdot R_1 - V_{BE} = 0$

$i_{R2} = i_C + i_B = i_E$

$V_{CC} - \beta \cdot i_B \cdot R_2 - i_B R_1 - V_{BE} = 0$

$(1+\beta) i_B R_2 + i_B R_1 = V_{CC} - V_{BE}$

$i_B = \dfrac{V_{CC} - V_{BE}}{(1+\beta)R_2 + R_1}$

$\dfrac{V_{CC} - v_C}{R_2} = i_{R2}$ $\boxed{v_C = V_{CC} - R_2 i_{R2}}$

$v_{CE} = v_C - 0 = V_{CC} - R_2 i_{R2} = V_{CC} - R_2(1+\beta) i_B = 1{,}18V > V_{CES}$

Q je u zas-u

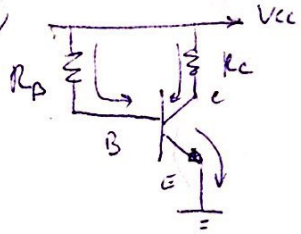
$i_E = i_B + i_C$ $i_C = \beta \cdot i_B$

$v_B = V_{BE} = 0{,}7V$

$v_E = 0$

---

(76)



$v_E = 0$ u n. zas

$v_{CE} > V_{CES}$?

$v_{CE} = V_{CC} - i_C R_C = V_{CC} - \beta \cdot i_B R_C$

$V_{CC} - i_C \cdot R_C - v_{CE} = 0$

$v_{CE} = V_{CC} - \beta \cdot R_C \cdot \dfrac{V_{CC} - V_{BE}}{R_B} = -4{,}17V < V_{CES}$

(1)

Huje zas

$V_{CC} - i_B R_B - V_{BE} = 0$

$i_B = \dfrac{V_{CC} - V_{BE}}{R_B}$

---

u n. zac

$V_{BE} = V_{BES}$ $v_{CE} = V_{CES}$ $\beta i_B > i_C$?

$\beta \cdot i_B = \beta \cdot \dfrac{V_{CC} - V_{BES}}{R_B} = 12mA$

$i_C = \dfrac{V_{CC} - V_{CES}}{R_C} = 0{,}28mA$

$\boxed{\beta i_B > i_C}$

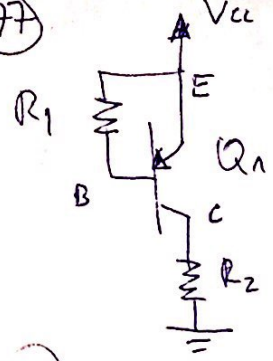
$v_B = V_{BES}$ $v_C = V_{CES}$

$v_E = 0$

$i_B = 120\mu A$ $i_C = 280\mu A$

$i_E = i_B + i_C = 400\mu A$

77)



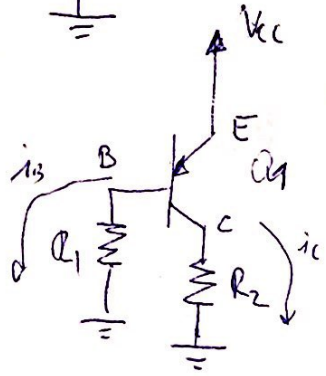
Q_1: gap bak $v_{EB} < V_\gamma$ $v_{EB} = 0 < V_\gamma$ (T)

$v_{EB} > V_{EBS}$?

$v_E = V_{CC}$ $v_E = V_{CC}$ $v_B = V_{CC}$

$i_C = 0,\ i_B = 0,\ i_E = 0$ $v_C = 0$

78)



Q_1: gap (T)

$v_E = V_{CC}$

$v_{EC} > V_{ECS}$ $v_C = +i_C R_2 = +\beta R_2 \cdot i_B$

$v_E = V_{CC}$ $V_{CC} - V_{EB} - i_B R_1 = 0$

$v_{CC} - V_{EB}$ $i_B = \dfrac{V_{CC} - V_{EB}}{R_1} = 57{,}4\,\mu A$

$v_{EC} = V_{CC} - \beta \cdot R_2 \cdot \dfrac{V_{CC} - V_{EB}}{R_1} = 6{,}3\,V > V_{ECS}$

$i_C = \beta i_B = 5{,}7\,mA$ $i_E = 5{,}757\,mA$

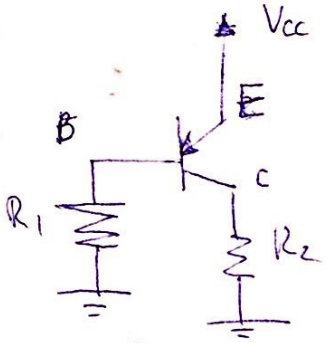
$v_E - v_C = v_{EC}$

$v_E = V_{CC}$

$v_B = v_E - V_{EB}$

$v_C = v_E - V_{EC}$

79)



Q: gap:

$v_E = V_{CC}$ ~~$v_{EB} > V_{EBS}$~~

$v_B = 0$ $v_{EB} < V_\gamma$ (T)

$v_C = 0$

$V_{CC} > V_\gamma$

Q: zar βi_B ~~$>$~~ i_C? v_{CC} ?

$v_{EB} = V_{EBS}$ $v_E - v_B = V_{EBS}$ $v_B = v_E - V_{EBS} = 11{,}4\,V$

$v_{EC} = V_{ECS}$ $v_E - v_C = V_{ECS}$ $v_C = v_E - V_{ECS} = 11{,}8\,V$ ($v_E = V_{CC}$)

$\beta i_B = \beta \dfrac{V_{CC} - V_{EBS}}{R_1} = 11{,}4\,mA$ $i_B = 1{,}14\,mA$

$i_E = 12{,}94\,mA$

$i_C = \dfrac{V_{CC} - V_{ECS}}{R_2} = 11{,}8\,mA$

Q: gap (T)

$v_{EB} = V_{EB}$

$v_{EC} > V_{ECS}$

$v_E = V_{CC} = 12\,V$

$V_{CC} - v_{EC} - i_C R_2 = 0$

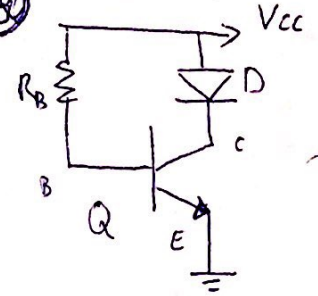
$v_{EC} = V_{CC} - i_C R_2 = V_{CC} - \beta R_2 \cdot \dfrac{V_{CC} - V_{EB}}{R_1} = -102\,V < V_{ECS}$

$i_C = \beta i_B$

$V_{CC} - V_{EB} - i_B R_1 = 0$

$i_B = \dfrac{V_{CC} - V_{EB}}{R_1}$

(80)



Q - OFF ∧ D OFF

$i_B = i_C = i_E = 0$

$v_B = V_{CC}$ $\quad v_{BE} < V_\gamma$

$V_{CC} < V_\gamma$ (1)

Q ON ∧ D ON

$v_{CE} > V_{CES}$?

$i_D > 0$? $\quad i_D = i_C$

$v_C = V_{CC} - V_D$ $\quad v_{CE} = V_{CC} - V_D > V_{CES}$ (1)

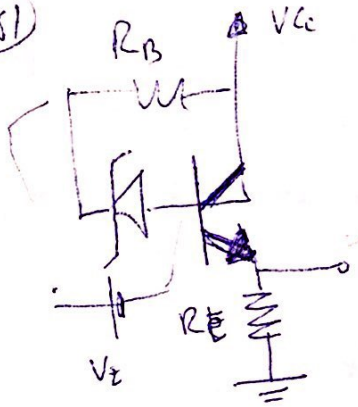
$v_E = 0$ $\quad v_{BE} = V_{BE}$ $\quad v_B = V_{BE}$ $\quad i_B = \frac{V_{CC} - V_{BE}}{R_B} = 120\,\mu A$

$i_C = \beta i_B = 12\,mA > 0$

$i_E = 12{,}12\,mA$

$v_B = 0{,}7\,V$

(81)



$v_i = V_{CC}$

min: gap

DZ: napięcie

$v_i = V_{CC}$

$v_{CE} > V_{CES}$?

$V_{CC} - i_B R_B - V_Z - V_{EB} - (1+\beta) i_B R_E = 0$

$\frac{V_{CC} - V_Z - V_{BE}}{R_B + (1+\beta) R_E} = i_B = 308{,}5\,\mu A$

$I_{DZ} < 0$

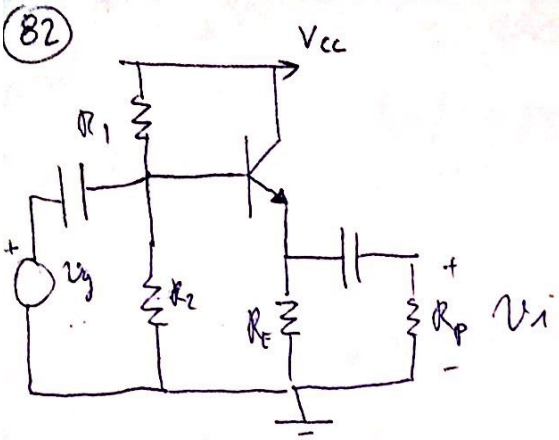
$v_E = v_i = (1+\beta) i_B \cdot R_E = 3{,}12\,V$

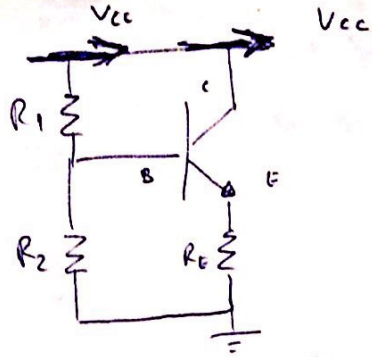
$v_{CE} = V_{CC} - (1+\beta) i_B R_E = 6{,}88\,V > V_{CES}$

δ)

$V_{CCX} = V_Z + V_{BE}$

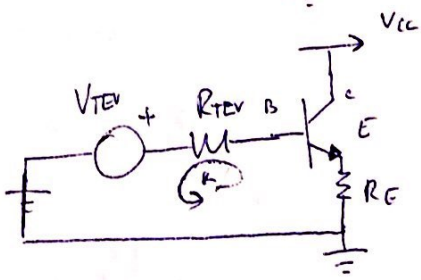
(82)





$V_{TEV} = \frac{R_2}{R_1+R_2} V_{cc} = 8V$

$R_{TEV} = \frac{R_1 R_2}{R_1+R_2} = 13k\Omega$



$(1+\beta) i_B$

$i_E R_E + V_{BE} + i_B R_{TEV} = V_{TEV}$

$I_B = \frac{V_{TEV} - V_{BE}}{(1+\beta)R_E + R_{TEV}} = 0,1mA$

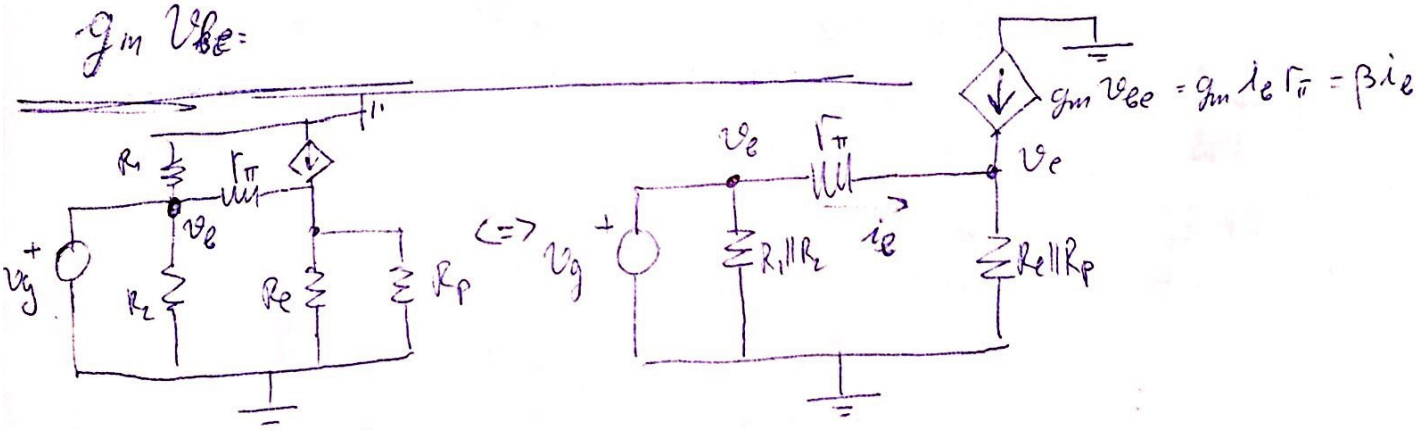
$I_C = \beta I_B = 10mA$ $\quad I_E = 10,1mA$ $\quad V_B = 6,7V$ $\quad V_C = V_{cc} - 12V$

$V_E = 6V$

$g_m = \frac{I_C}{V_t} = 384,6mS$

$r_\pi = \frac{\beta}{g_m} = 260\Omega$

$g_m v_{be}$:



$i_b + \beta i_b = \frac{v_i}{R_e \| R_P}$ $\quad i_b = \frac{v_g - v_i}{r_\pi}$

$i_b = \frac{v_i}{(1+\beta) R_e \| R_P}$ $\quad \frac{v_g - v_i}{r_\pi} = \frac{v_i}{(1+\beta) R_e \| R_P}$ $\quad v_i \left(\frac{1}{(1+\beta) R_e \| R_P} + \frac{1}{r_\pi} \right) = \frac{v_g}{r_\pi}$

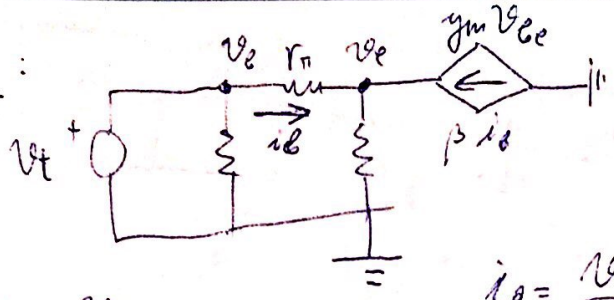
$v_i = \frac{(1+\beta) R_e \| R_P}{r_\pi} (v_g - v_i)$

$v_i \left(1 + \frac{(1+\beta) R_e \| R_P}{r_\pi} \right) = v_g \cdot \frac{(1+\beta) R_e \| R_P}{r_\pi}$

$\boxed{v_i = v_g \frac{(1+\beta) R_e \| R_P}{r_\pi + (1+\beta) R_e \| R_P}}$

$a = \frac{v_i}{v_g} = \frac{(1+\beta) R_e \| R_P}{r_\pi + (1+\beta) R_e \| R_P} \approx 0,993$

R_{VL}:



$$i_t = \frac{v_t}{R_1 \| R_2} + i_e$$

$$i_e = \frac{v_t - v_e}{r_\pi}$$

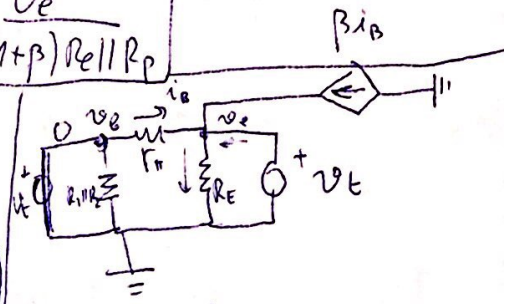
$$v_e = \frac{(1+\beta) i_b \, R_e \| R_p}{R_e + R_p}$$

$$\frac{v_e}{(1+\beta) R_e \| R_p} = \frac{v_t - v_e}{r_\pi} \quad / \cdot v_e \cdot r_\pi$$

$$\frac{r_\pi}{(1+\beta) R_e \| R_p} = \frac{v_t}{v_e} - 1$$

$$v_e = v_t \left(\frac{(1+\beta) R_e \| R_p}{r_\pi + (1+\beta) R_e \| R_p} \right)$$

$$i_e = \frac{v_e}{(1+\beta) R_e \| R_p}$$



$$(1+\beta) i_B + i_t = \frac{v_t}{R_e}$$

$$i_t = \frac{v_t}{R_e} - (1+\beta) i_B$$

$$i_B = -\frac{v_t}{r_\pi}$$

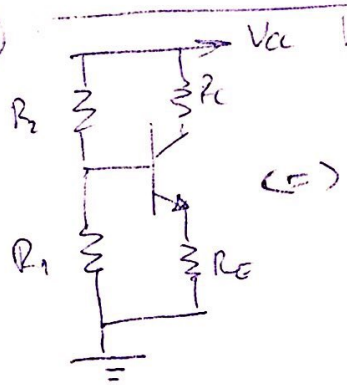
$$i_t = v_t \left(\frac{1}{R_e} + \frac{1+\beta}{r_\pi} \right)$$

$$R_{1EL} = \left(\frac{1}{R_e} + \frac{1+\beta}{r_\pi} \right)^{-1}$$

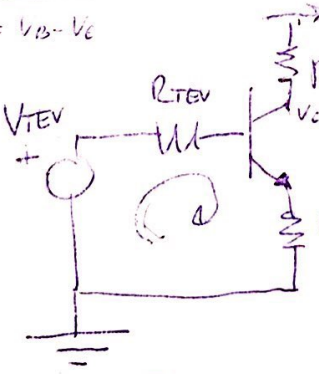
$$i_t = \frac{v_t}{R_1 \| R_2} + v_t \left(\frac{1 - \frac{(1+\beta) R_e \| R_p}{r_\pi + (1+\beta) R_e \| R_p}}{r_\pi} \right)$$

$$R_{VL} = \frac{v_t}{i_t} = \left(\frac{1}{R_1 \| R_2} + \frac{1}{r_\pi + (1+\beta) R_e \| R_p} \right)^{-1}$$

(X4)



$\Leftrightarrow$



$V_{BE} = V_B - V_E$

$$V_{TEV} = \frac{R_1}{R_1 + R_2} V_{CC}$$

$$R_{TEV} = R_1 \| R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

$$V_{TEV} - V_{BE} = I_B (R_{TEV} + (1+\beta) R_E)$$

$$I_B = \frac{V_{TEV} - V_{BE}}{R_{TEV} + (1+\beta) R_E} = 16{,}57\,\mu A$$

$$I_E = I_B + I_C \qquad I_C = \beta I_B$$

$$V_{TEV} - I_B \cdot R_{TEV} - V_{BE} - I_E \cdot R_E = 0$$

$$I_C = 1{,}657\,mA$$

$$I_E = 1{,}674\,mA$$

$$V_{CC} - V_C = R_C I_C$$

$$\frac{V_{TEV} - V_B}{R_{TEV}} = I_B$$

$$V_B = I_B R_{TEV}$$

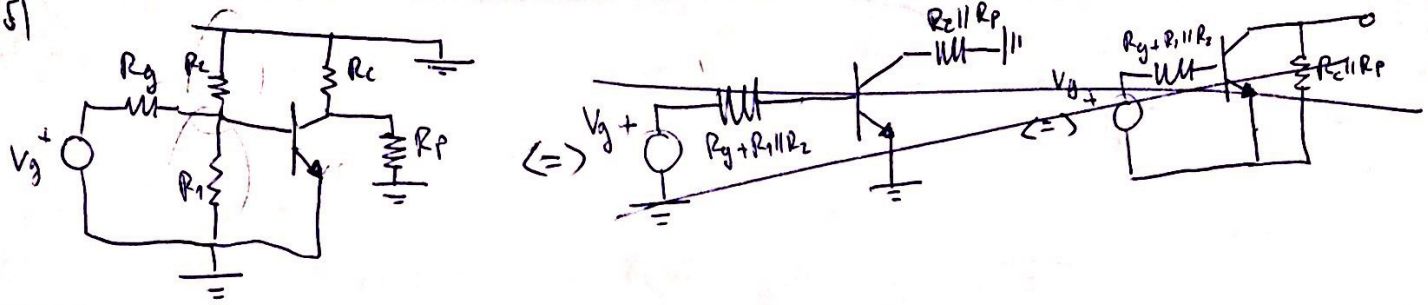
$$V_{TEV} -$$

$$V_E = R_E \cdot I_E$$

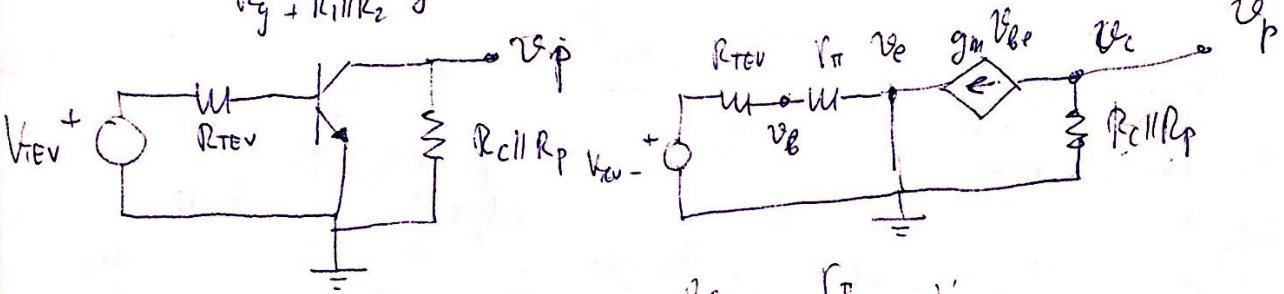
$$V_B = V_{BE} + V_E$$

$$V_C = V_{CC} - R_C I_C$$

5)



$$V_{TEV} = \frac{R_1 \parallel R_2}{R_g + R_1 \parallel R_2} v_g \qquad R_{TEV} = R_g \parallel R_2 \parallel R_3$$



$$v_p = -g_m v_{be} \cdot R_c \parallel R_p \qquad v_{be} = \frac{r_\pi}{R_{TEV} + r_\pi} \cdot V_{TEV}$$

$$v_p = -\frac{I_c}{V_t} \cdot \frac{r_\pi}{R_{TEV} + r_\pi} \cdot R_c \parallel R_p \cdot \frac{R_1 \parallel R_2}{R_g + R_1 \parallel R_2} \cdot v_g$$

$$\frac{v_p}{v_g} = -\frac{I_c}{V_t} \cdot \frac{r_\pi}{R_{TEV} + r_\pi} \cdot R_c \parallel R_p \cdot \frac{R_1 \parallel R_2}{R_g + R_1 \parallel R_2}$$

$$R_{VL} = R_g + R_1 \parallel R_2 \parallel r_\pi$$

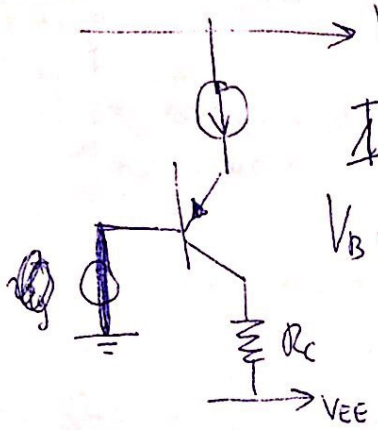
$$R_{iL} = R_c$$

$v_{be} = 0$

$g_m v_{be} = 0$

(84) $\beta = 50$

DC:



$I_E = I_R$

$V_B = V_g$

$I_B = \frac{I_E}{1+\beta}$

$I_C = \frac{\beta}{1+\beta} I_E$

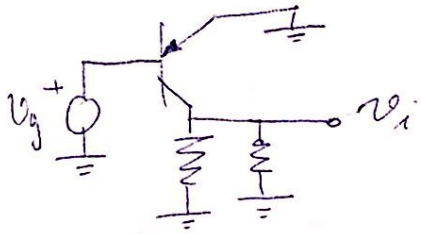
$V_B = 0$

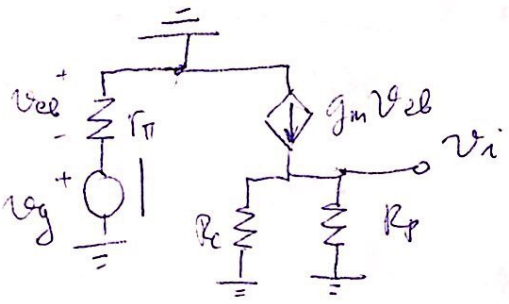
$V_C = I_C R_C + V_{EE}$

$V_{EB} = V_E - V_B$

$V_E = V_{EB}$

$g_m = \frac{I_C}{V_T}$ $\quad r_\pi = \frac{\beta}{g_m}$





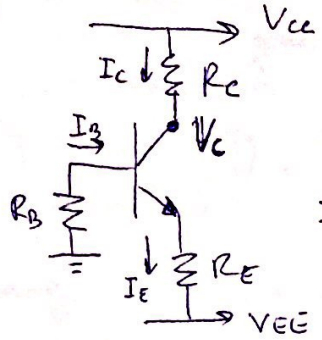
$v_i = g_m v_{eb} \cdot R_c \| R_p$ $\quad v_{eb} = -v_g$

$\boxed{v_i = -g_m v_g \cdot R_c \| R_p}$ $\quad a = -g_m R_c \| R_p$

$R_{UL} = r_\pi$

$R_{IZL} = R_C$

(85)



$V_{EE} + I_E R_E + V_{BE} + I_B R_B = 0$ $\quad I_B = -\frac{V_{EE} + V_{BE}}{(1+\beta)R_E + R_B}$

$0 - I_B R_B - V_{BE} - I_E R_E + V_{EE} = 0$

$I_B = \frac{V_{EE} - V_{BE}}{(1+\beta)R_E + R_B}$

$I_E = (1+\beta) I_B$

$I_B((1+\beta)R_E + R_B) = V_{EE} - V_{BE}$

$V_{EE} + (1+\beta) I_B R_E + V_{BE} + I_B R_B = 0$

$g_m = \frac{I_C}{V_T} = 33{,}72\ mS$

$I_B = -\frac{V_{EE} + V_{BE}}{(1+\beta)R_E + R_B} = 8{,}43\ \mu A$

$r_\pi = \frac{\beta}{g_m}$

$I_C = 843\ \mu A$ $\quad I_E = 851{,}4\ \mu A$

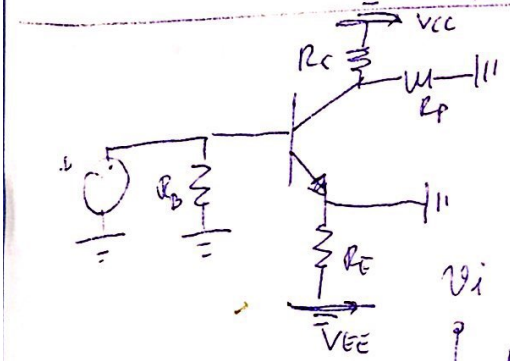
$V_E = I_E R_E + V_{EE} = -0{,}9956\ V$

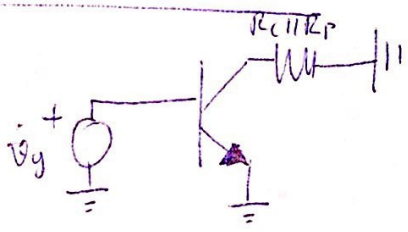
$V_{BE} = V_B - V_E$

$V_B = V_{BE} + V_E = -0{,}396\ V$

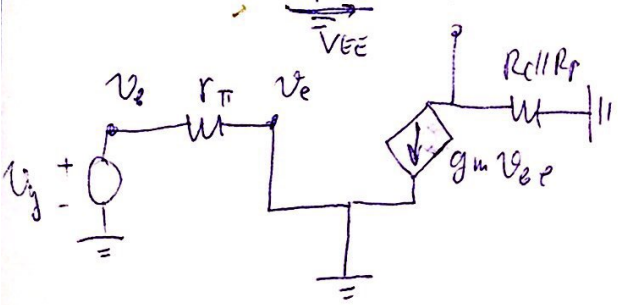
$\frac{V_{CC} - V_C}{R_C} = I_C$

$V_C = V_{CC} - R_C I_C = 1{,}038\ V$





$R_C \parallel R_P = \frac{R_C R_P}{R_C + R_P} = 3{,}12\ k\Omega$



$\frac{0 - v_i}{R_C \parallel R_P} = g_m v_{be}$

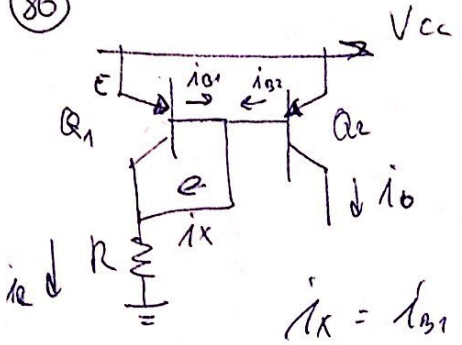
$v_i = -g_m v_{be} R_C \parallel R_P$

$A_i = -g_m R_C \parallel R_P \approx -108$

$R_{UL} = R_B \parallel r_\pi$

$R_{IZL} = R_C$

(86)



$$i_C = i_{C1} = i_O$$

$$\Downarrow$$

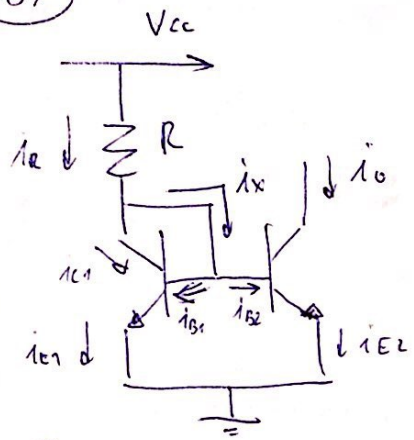
$$i_{B1} = i_{B2}$$

$$i_X = i_{B1} + i_{B2} = 2 i_B$$

$$i_R = i_{C1} + 2 i_B = i_B(2+\beta)$$

$$i_B = \frac{i_R}{2+\beta} \qquad i_O = \frac{\beta\, i_R}{2+\beta} = \frac{\beta}{2+\beta} \cdot \frac{V_{CC} - V_{EB}}{R}$$

(87)



$$i_{C1} = i_{C2} = i_O$$

$$i_X = i_{B1} + i_{B2} = 2 i_B$$

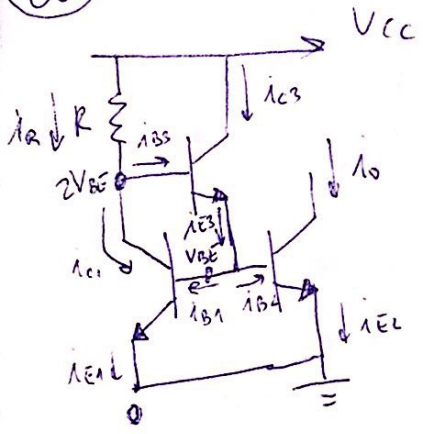
$$i_R = i_E + 2 i_B$$

$$i_O = i_X - 2 i_B$$

$$i_R = i_B(\beta+2)$$

$$i_C = \frac{\beta}{\beta+2} i_R = \frac{\beta}{2+\beta} \cdot \frac{V_{CC} - V_{BE}}{R}$$

(88)



$$i_{C1} = i_{C2} = i_O$$

$$i_{E3} = 2 i_B$$

$$(1+\beta)\, i_{B3} = 2 i_B$$

$$i_R = i_{B3} + i_{C1} = i_{B3} + \frac{\beta(1+\beta) i_{B3}}{2} = i_{B3}\left(1 + \frac{\beta(\beta+1)}{2}\right)$$

$$i_R = \frac{V_{CC} - 2V_{BE}}{R} \qquad i_{B3} = \frac{2}{1+\beta} i_B$$

$$i_B = \frac{(1+\beta) i_{B3}}{2} \qquad i_{C1} = \beta i_B = \frac{\beta(1+\beta) i_{B3}}{2}$$

$$i_R = \frac{2}{1+\beta} i_B + \beta i_B \Rightarrow \quad i_B = \frac{i_R}{\left(\frac{2}{(1+\beta)} + \beta\right)}$$

$$i_C = \beta i_B = \frac{V_{CC} - 2V_{BE}}{R\left(1 + \frac{2}{\beta(1+\beta)}\right)}$$