Ηλεκτρονική Ι

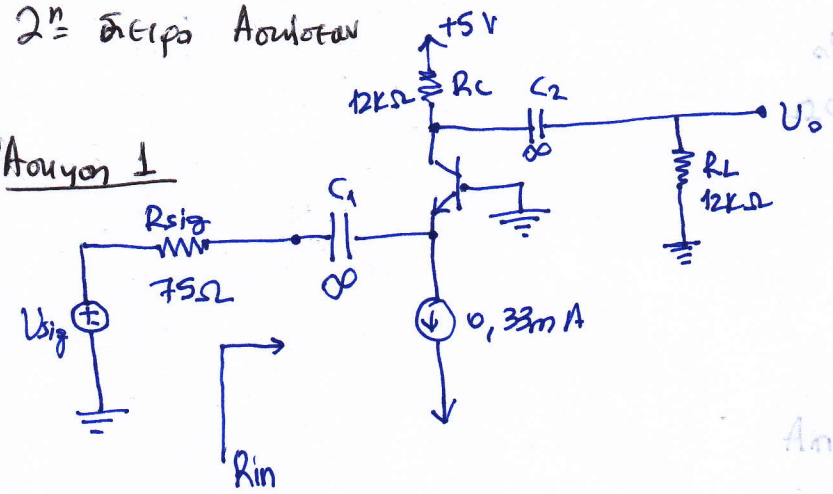
4ο Εξάμηνο, 2018-2019

2η Σειρά Ασκήσεων

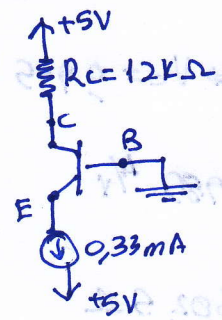
Χρήστος Τσούφης

03117176

Άσκηση 1



DC Ανάλυση:



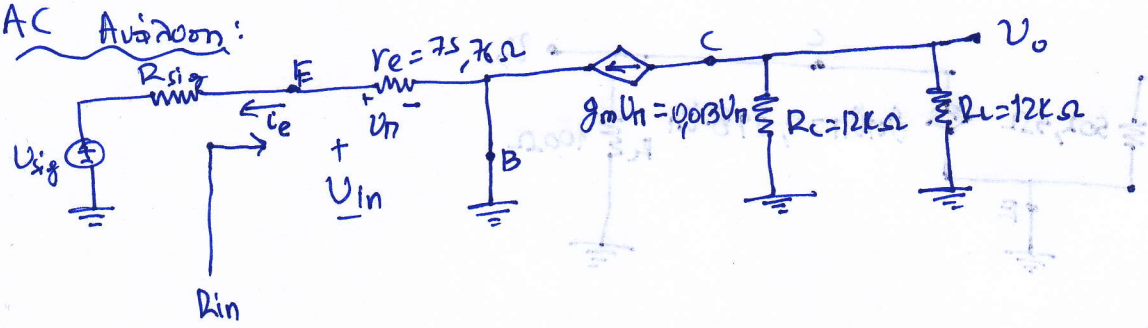
$I_E = 0,33mA$

$I_C = a \cdot I_E = 0,3267mA$

$g_m = \frac{I_C}{V_T} = 0,0135$

$r_e = a \cdot \frac{V_T}{I_C} = \frac{0,99 \cdot 25mV}{0,3267mA} \Rightarrow r_e = 75,76\,\Omega$

AC Ανάλυση:

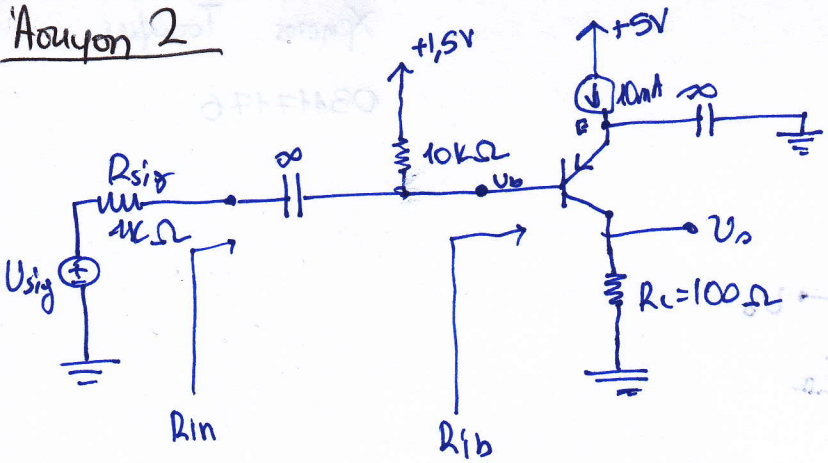


$$\frac{v_o}{v_{sig}} = \frac{R_c \| R_L \cdot i_c}{v_{sig}} = \frac{R_c \| R_L \cdot g_m v_\pi}{v_{sig}} = \frac{R_c \| R_L \cdot g_m r_e \cdot i_e}{v_{sig}} = \frac{R_c \| R_L \cdot g_m r_e v_{sig}}{(R_{sig} + r_e) \cdot v_{sig}} =$$

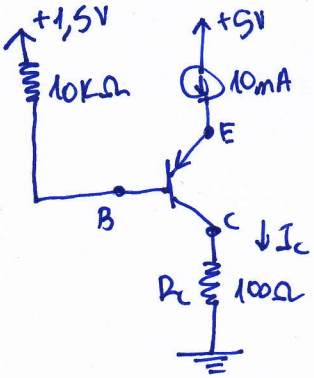
$$= \frac{R_c \| R_L \cdot I_C \cdot a \cdot V_T}{V_T \cdot I_C \cdot (R_{sig} + r_e)} = a \frac{R_c \| R_L}{R_{sig} + r_e} = 0,99 \frac{12k \| 12k}{75\Omega + 75,76\Omega} = \frac{0,99 \cdot 6000}{150,76} = 39,4$$

$$R_{in} = \frac{v_{in}}{-i_e} = \frac{+i_e r_e}{+i_e} \Rightarrow R_{in} = r_e = 75,76\,\Omega$$

Άσκηση 2



DC Ανάλυση:



$I_E = 10mA$

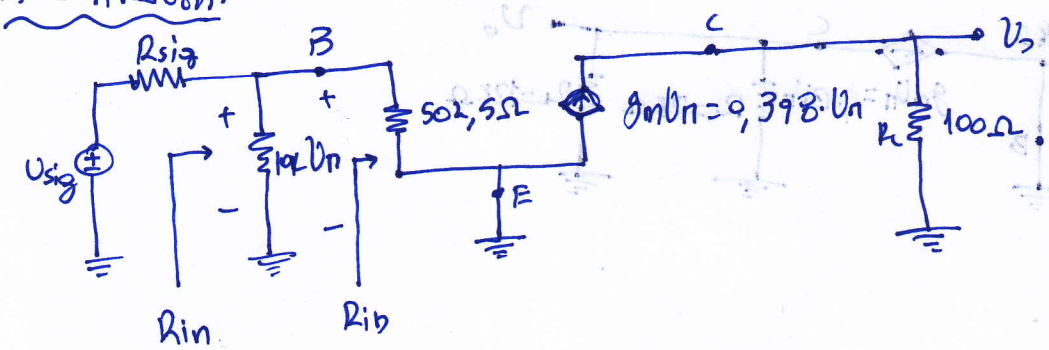
$I_c = \frac{\beta}{\beta+1} I_E = \frac{200}{201} \cdot 10mA \Rightarrow I_c = 9,95mA$

ΝΤΚ: $V_c = 100\Omega \cdot I_c = 100 \cdot 9,95mA \Rightarrow V_c = 0,995\ V$

$g_m = \frac{I_c}{V_T} = \frac{9,95mA}{25mV} \Rightarrow g_m = 0,3985\ A/V$

$r_\pi = \beta \frac{V_T}{I_c} = 200 \cdot \frac{25mV}{9,95mA} \Rightarrow r_\pi = 502,5\Omega$

AC Ανάλυση:



$R_{in} = \frac{V_{in}}{i_{sig}} = \frac{10K \| 502,5 \cdot V_{sig}}{10K \| 502,5 + R_{sig}} \cdot \frac{1}{V_{sig}} = 10K \| 502,5 \Rightarrow R_{in} = 478,45\Omega$

$= 0,478K\Omega$

$R_{ib} = \frac{V_\pi}{i_b} = \frac{r_\pi \cdot i_b}{i_b} \Rightarrow R_{in} = r_\pi = 502,5\Omega$

$\frac{V_\pi}{V_{sig}} = \frac{R_{in}}{R_{in}+R_{sig}} = \frac{0,478}{0,478+1} = 0,323\frac{V}{V}$

$\begin{cases} \frac{V_o}{V_\pi} = -g_m R_c = -0,3985 \cdot 100 = -39\frac{V}{V} \\ \frac{V_o}{V_{sig}} = -39 \cdot 0,323 = -12,6\frac{V}{V} \end{cases}$

Αν $U_o = 0{,}4V$ τότε,

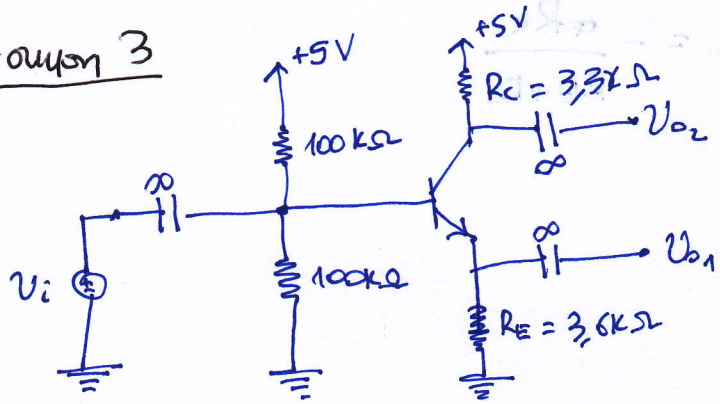
$$U_o = 100 \cdot i_c = 100 \cdot g_m \cdot v_\pi = 100 \cdot g_m \cdot i_b \cdot r_\pi = 100 \cdot g_m \cdot r_\pi \cdot \frac{10K}{10K + 502{,}5} \cdot i_{sig} \Rightarrow$$

$$\Rightarrow U_o = \frac{100 \cdot g_m \cdot r_\pi \cdot 10K}{10K + 502{,}5} \cdot \frac{U_{sig}}{R_{sig} + 10K \| 502{,}5} \Rightarrow U_{sig} = \frac{(10 \cdot 502{,}5\Omega) \cdot (1{,}478{,}5\Omega) \cdot 0{,}4V}{100\Omega \cdot 502{,}5\Omega \cdot 10K\Omega \cdot 0{,}398} \Rightarrow$$

$$\Rightarrow U_{sig} \simeq \pm 0{,}03V$$

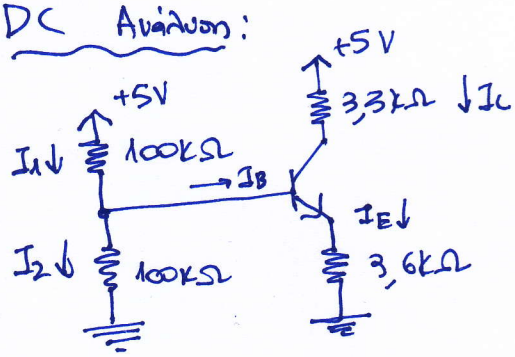
$$U_b = U_{sig} - i_{sig} \cdot R_{sig} = U_{sig} - \frac{U_{sig}}{1478{,}45} R_{sig} = \pm 0{,}13V$$

Άσκηση 3



$\beta = \infty$

DC Ανάλυση:



$\beta = \infty$: $I_C = I_E$, $I_B = 0$

ΝΡΚ: $I_1 = I_2 = I = \frac{5}{200K} = 0{,}025mA$

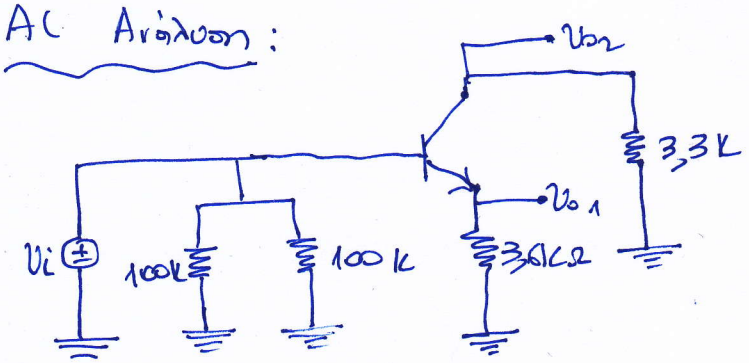
ΝΤΚ: $5 - I \cdot 100K = V_B \Rightarrow V_B = 5 - 2{,}5 \Rightarrow V_B = 2{,}5V$

(Ενεργός περιοχή $V_{BE} = 0{,}7V$)

Άρα $V_E = 1{,}8V$

ΝΤΙΚ: $V_E - I_E \cdot 3{,}6K = 0 \Rightarrow I_E = \frac{1{,}2V}{3{,}6K\Omega} \Rightarrow I_E = 0{,}5mA = I_C$

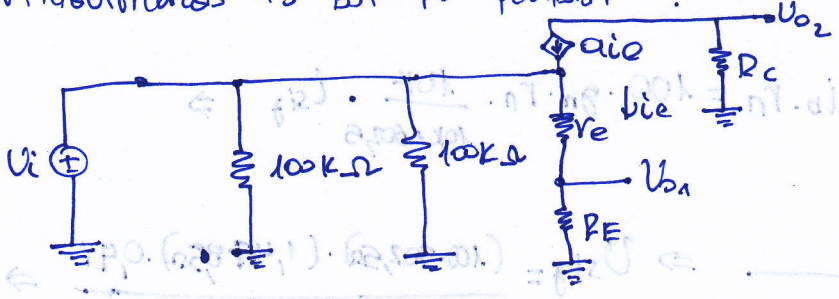
AC Ανάλυση:



$$g_m = \frac{I_C}{V_T} = 9{,}02$$

$$r_e = \alpha \frac{V_T}{I_C} = 50$$

ΑΝΤΙΣΤΟΙΧΕΣ ΤΟ BJT ΕΙΝΑΙ ΠΟΥΛΗΣΤ :



$$i_e = \frac{v_i}{R_E + r_e}$$

$$v_{o_1} = i_e R_E = v_i \cdot \frac{R_E}{R_E + r_e} \Rightarrow \frac{v_{o_1}}{v_i} = \frac{R_E}{R_E + r_e}$$

$$v_{o_2} = -\alpha \cdot i_e R_C = -\alpha \frac{v_i}{R_E + r_e} \cdot R_C \Rightarrow \frac{v_{o_2}}{v_i} = -\frac{\alpha R_C}{R_E + r_e}$$

• Για $\alpha \simeq 1$:

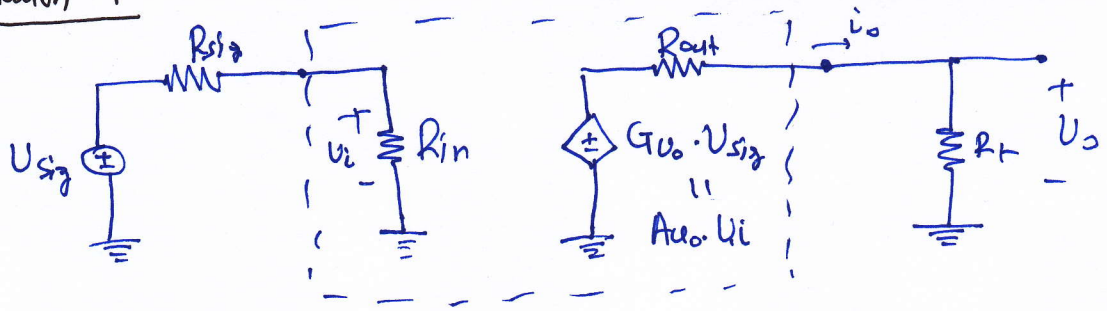
$$r_e = \frac{V_T}{I_E} = \frac{25mV}{0,5mA} = 50\Omega$$

$$\frac{v_{o_1}}{v_i} = \frac{3,6}{3,6 + 0,05} = 0,986 \ V/V$$

$$\frac{v_{o_2}}{v_i} = -\frac{3,3}{3,6 + 0,05} = 0,904 \ V/V$$

• $$\frac{v_{o_2}}{v_i} = -\frac{\alpha R_C}{r_e} = -\frac{3,3}{0,05} = -66 \frac{V}{V}$$

Άσκηση 4



$$G_{Vo} = \frac{V_o}{U_{sig}}\Big|_{R_L=\infty} \quad , \quad G_{Vo} = \frac{R_{in}}{R_{in}+R_{sig}}\Big|_{R_L=\infty} \cdot A_{vo} \quad , \quad A_{vo} = \frac{U\phi}{v_i}\Big|_{R_i=\infty} \quad , \quad R_i = \frac{R_{in}}{R_L} = \infty$$

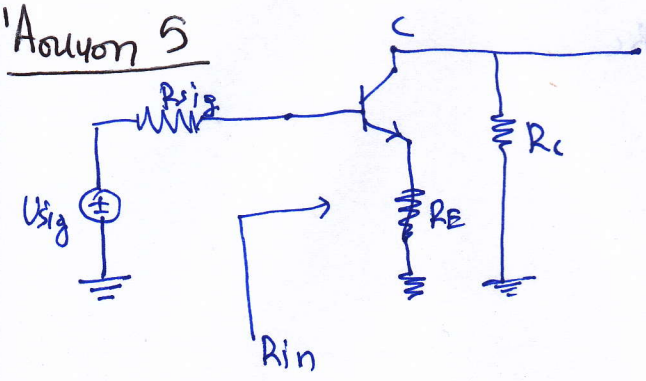
$$R_L=\infty, \quad G_{Vo} = \frac{R_i}{R_i+R_{sig}} A_{vo} \quad , \quad G_{Vs} = G_{Vo}\frac{R_L}{R_L+R_{out}}$$

Για $R_L=\infty$, $G_{vo} = \frac{v_o}{i_i}\cdot\frac{v_i}{v_{sig}} = A_{vo}\cdot\frac{v_i}{v_{sig}} = A_{vo}\cdot\frac{i_{sig}\cdot R_i}{v_{sig}}$

$$G_{vo} = \frac{R_i}{R_i+R_{sig}}\cdot A_{vo}$$

Για R_L πεπερ., $G_v = \frac{v_o}{v_{sig}} = \frac{R_L}{R_L+R_{out}}\cdot G_{vo}\cdot v_{sig}\cdot\frac{1}{v_{sig}} \Rightarrow G_v = \frac{R_L}{R_L+R_{out}}\cdot G_{Vo}$ (διαιρέση τάσης)

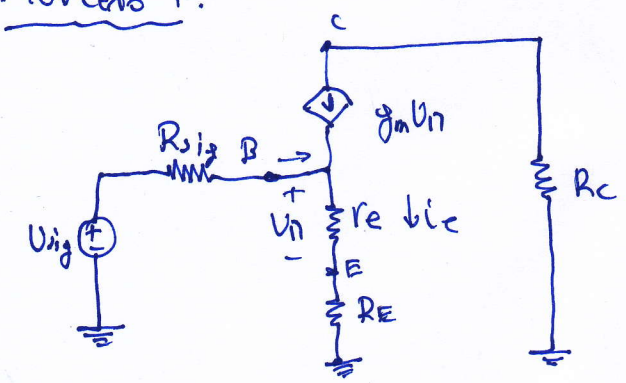
Άσκηση 5



$\beta = 74$, $R_{in} = 15K\Omega$

$\hat{U}_{sig} = 9{,}15V$, $R_{sig} = 30K\Omega$ και $\hat{U}_{in} = 5mV$

Μοντέλο Τ:



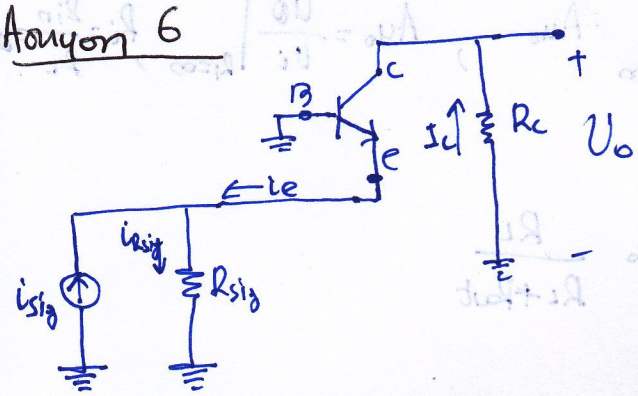
$$R_{in} = (\beta+1)(r_e+R_E)$$

$$R_E + r_e = \frac{R_{in}}{\beta+1}$$

$$U_\pi = \frac{r_e}{R_{sig}+R_E+r_e}U_{sig} \Rightarrow U_\pi(R_{sig}+R_E+r_e) = U_{sig}\cdot r_e$$

$$r_e = \frac{\beta}{\beta+1}\cdot\frac{V_T}{I_C} \Rightarrow I_C = \frac{\beta V_T}{(\beta+1)\cdot r_e}$$

Άσκηση 6



$R_{sig} \gg r_e$, $\alpha \simeq 1$

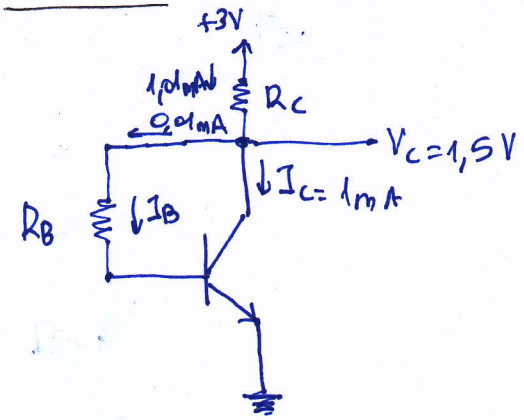
$\alpha \simeq 1 \Rightarrow i_c \simeq i_e$

NTK: $V_{BE} = i_{R_{sig}} \cdot R_{sig} \Rightarrow i_{R_{sig}} = \dfrac{V_{BE}}{R_{sig}}$

$$i_e = i_{R_{sig}} - i_{sig} \Rightarrow i_e = i_c = \frac{V_{BE}}{R_{sig}} - i_{sig}$$

$$v_o = -i_c \cdot R_c \Rightarrow v_o = \left(i_{sig} - \frac{V_{BE}}{R_{sig}}\right) R_c$$

Άσκηση 7



α) $R_C = \frac{3-1,5}{1,01\,mA} \simeq 1,5K\Omega$

$1,5 = 0,01 R_B + V_{BE} = 0,01 R_B + 0,7 \Rightarrow R_B = 80K\Omega$

β) 5%: $R_C = 1,5K\Omega$, $R_B = 82K\Omega$

$I_E = \frac{V_{CC} - V_{BE}}{R_C + \frac{R_B}{\beta+1}} = \frac{3-0,7}{1,5+\frac{82}{101}} = 0,99mA$

$I_C = \alpha I_E = 0,99 \times 0,99 = 0,98mA$

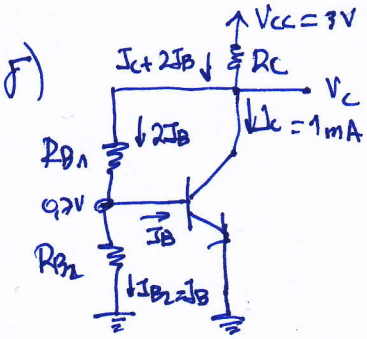
$V_C = 3 - 1,5 \times 0,99 = 1,52V$

γ) $\beta = \infty$:

$I_C = I_E = \frac{V_{CC} - V_{BE}}{R_C} = \frac{3-0,7}{1,5} = 1,53mA$

$V_C = 0,7V$

δ)



$I_B = \frac{I_C}{\beta} = \frac{1}{100} = 0,01mA$

$R_{B_2} = \frac{0,7}{I_{B_2}} = \frac{0,7}{0,01} = 70K\Omega$

$1,5 = 2I_B \cdot R_{B_1} + 0,7 \Rightarrow 0,8 = 2 \cdot 0,01 \cdot R_{B_1} \Rightarrow R_{B_1} = 40K\Omega$

$R_C = \frac{3-1,5}{I_C + 2I_B} = \frac{1,5}{1,02} = 1,47K\Omega$

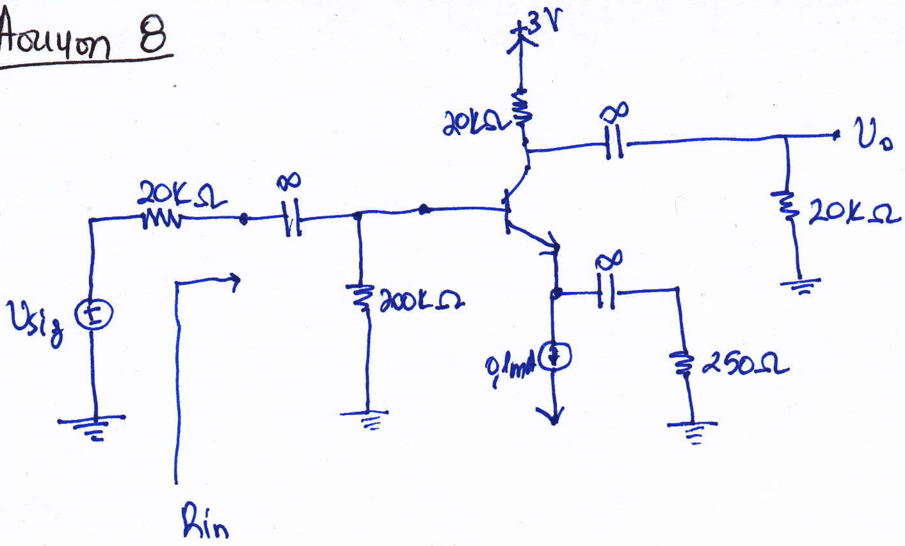
Για $\beta = \infty$: $I_B = 0$, $I_{B_2} = \frac{0,7}{R_{B_2}} = \frac{0,7}{70} = 0,01mA$

$I_{B_1} = I_{B_2} = 0,01mA$

$V_C = 0,01 R_{B_1} + 0,7 = 0,01 \cdot 40 + 0,7 = 1,1V$

$I_C + 0,01 = \frac{3-1,1}{R_C} = \frac{3-1,1}{1,47} = 1,29 \Rightarrow I_C = 1,28mA$

Άσκηση 8



$I_E = 0,1mA$

$r_e = \frac{V_T}{I_E} = \frac{25mV}{0,1mA} = 250\Omega$

$g_m = \frac{I_C}{V_T} \simeq \frac{0,1mA}{0,025V} = 4 mA/V$

$R_e = 250\Omega$

$R_{in} = 200k\Omega // (\beta+1)(r_e+R_e) = 200 // [101 \times (0,25+0,25)] = 200 // 50,5 = 40,3K\Omega$

$\frac{V_b}{V_{sig}} = \frac{R_{in}}{R_{in}+R_{sig}} = \frac{40,3}{40,3+20} \simeq 0,668 \, V/V$

$\frac{V_o}{V_b} = -\alpha \frac{\text{Ολική Αντισ. Συλλέκτη}}{\text{Ολική Αντισ. Εκπομπού}} \simeq - \frac{20//20}{0,25+0,25} = -20 \, V/V$

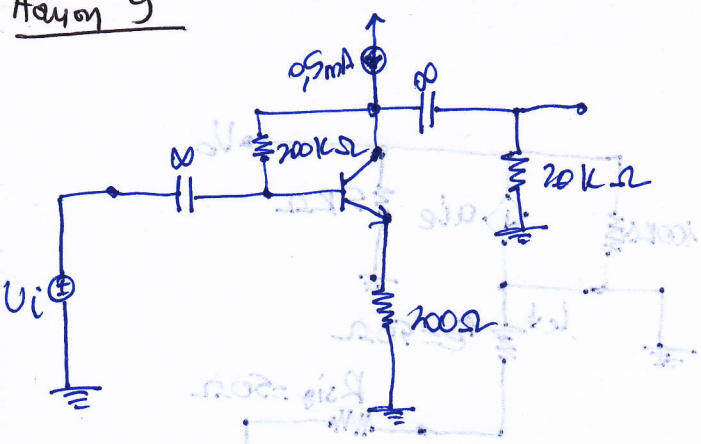
$G_V = \frac{V_o}{V_{sig}} = \frac{V_o}{V_b} \cdot \frac{V_b}{V_{sig}} = -0,668 \times 20 = -13,4 \, V/V$

Για V_{be} περιορ. στα 5mV, το μέγ. πλάτος βάσης και γύρω θα είναι 10mV.

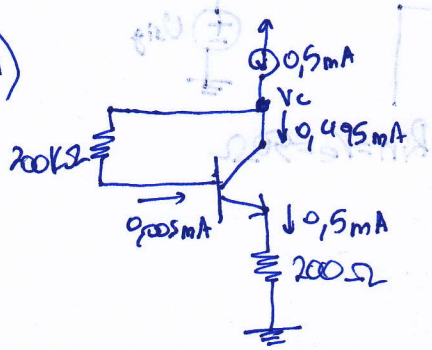
$\hat{V}_{sig} = \frac{10mV}{\frac{V_b}{V_{sig}}} = \frac{10mV}{0,668 \frac{V}{V}} = 15mV$

Όμοια, $\hat{V}_o = |G_V| \cdot \hat{V}_{sig} = 13,4 \times 15 = 200mV = 0,2V$

Άσκηση 9



α)



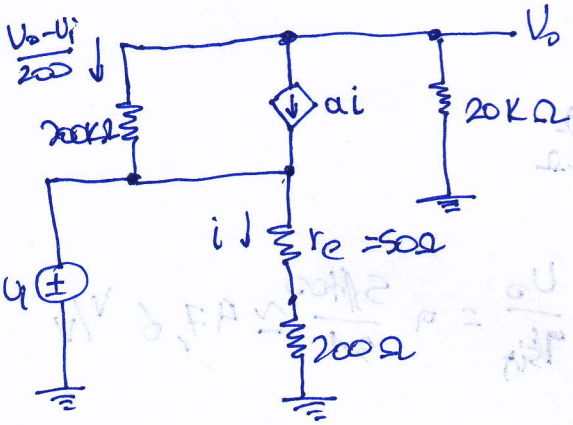
$I_C = 0,495\,mA$

$V_C = I_B \times 200K\Omega + I_E \times 0,2K\Omega + V_{BE}$

$= 0,005 \times 200 + 0,5 \times 0,2 + 0,7$

$= 1,18V$

β)



$g_m = \frac{I_c}{V_T} = \frac{0,495}{0,025} \simeq 20\,mA/V$

$r_e = \frac{V_T}{I_E} = 50\Omega$

$i = \frac{Vi}{re+Re} = \frac{Vi}{50+200} = \frac{Vi}{250} = 4Vi\ (mA)$

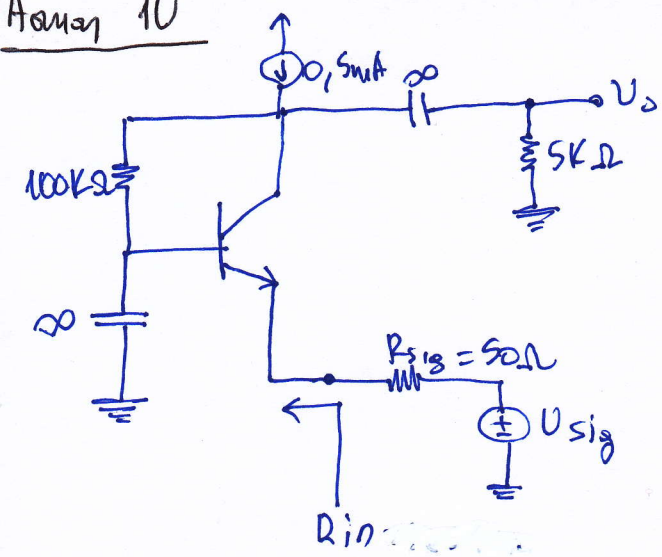
$\frac{V_o}{20} + ai + \frac{V_o - Vi}{200} = 0 \Rightarrow$

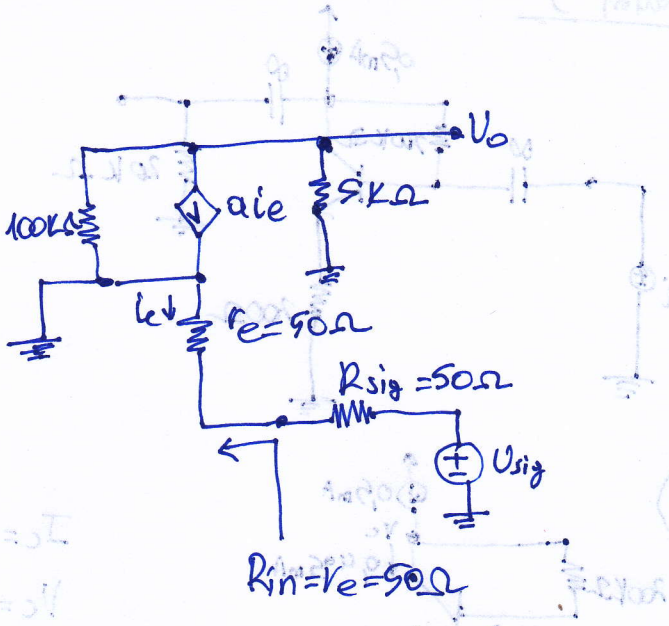
$\Rightarrow \frac{V_o}{20} + 0,99 \times 4Vi + \frac{V_o}{200} - \frac{Vi}{200} = 0$

$\Rightarrow V_o\left(\frac{1}{20} + \frac{1}{200}\right) = -Vi\left(4 \cdot 0,99 - \frac{1}{200}\right)$

$\Rightarrow \frac{V_o}{Vi} = -71,9\ \frac{V}{V}$

Άσκηση 10





$$I_C = \alpha I_E \simeq 0{,}5mA$$

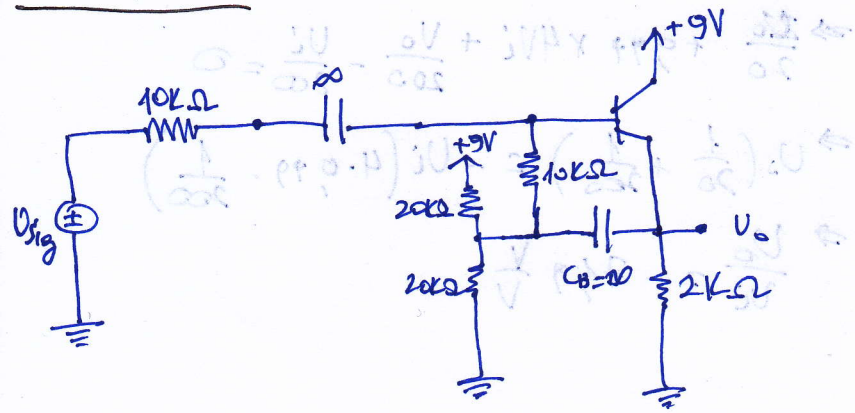
$$r_e = \frac{V_T}{I_E} = \frac{25mV}{0{,}5mA} = 50\Omega$$

$$R_{in} = r_e = 50\Omega$$

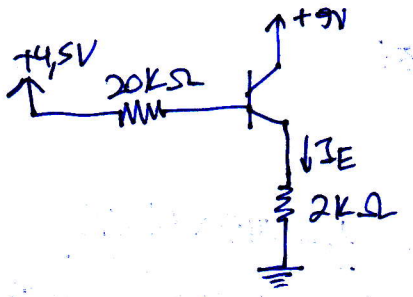
$$i_e = -\frac{V_{sig}}{r_e + R_{sig}} = -\frac{U_{sig}}{50+50} = -\frac{U_{sig}}{100} = -\frac{U_{sig}}{0{,}1K\Omega}$$

$$V_o = -\alpha \cdot i_e \,(5 \,//\, 100) = \alpha \frac{U_{sig}}{0{,}1} \cdot (5 \,//\, 100) \Rightarrow \frac{U_o}{U_{sig}} = \alpha \frac{5 \,//\, 100}{0{,}1} \simeq 47{,}6 \; V/V$$

Άσκηση 11



DC 1000. (y Thevenin):



a) $I_E = \frac{4,5-0,7}{2+\frac{20}{\beta+1}} = \frac{3,8}{2+\frac{20}{101}} = 1,73\,mA$

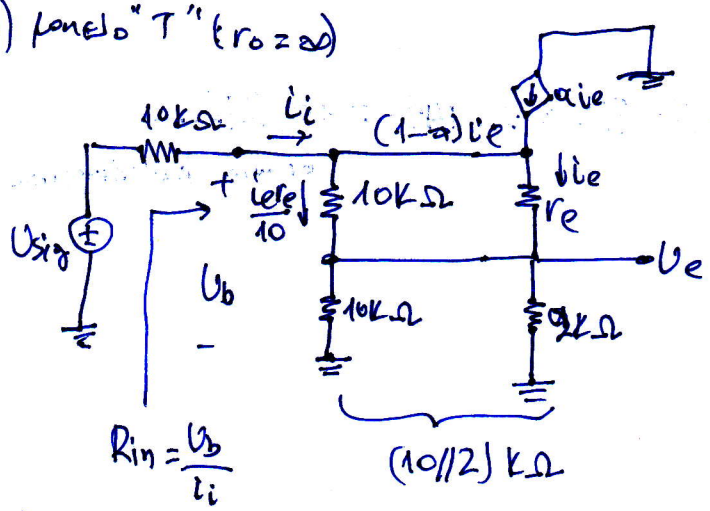
$I_C = \alpha I_E = 0,99 \times 1,73mA = 1,71mA$

$g_m = \frac{I_C}{V_T} = 68,4\,mA/V$

$r_e = \frac{V_T}{I_E} = \frac{25mV}{1,73mA} = 14,5\Omega = 0,0145\,K\Omega$

$r_\pi = (\beta+1) r_e = 101 \times 0,0145 = 1,4645\,K\Omega$

β) Modelo "T" ($r_o = \infty$)



$V_e = (i_e + i_e \frac{r_e}{10})(10//2)$

$V_b = V_e + i_e r_e = i_e (10//2) \cdot (1 + \frac{r_e}{10}) + i_e r_e$

$i_i = (1-\alpha) i_e + i_e \frac{r_e}{10} = \frac{i_e}{\beta+1} + i_e \frac{r_e}{10}$

$R_{in} = \frac{V_b}{i_i} = \frac{(10//2) \cdot (1+\frac{r_e}{10}) + r_e}{\frac{1}{\beta+1} + \frac{r_e}{10}} = \frac{(\beta+1)(10//2)(1+\frac{r_e}{10}) + (\beta+1) r_e}{(\beta+1)\frac{r_e}{10} + 1} =$

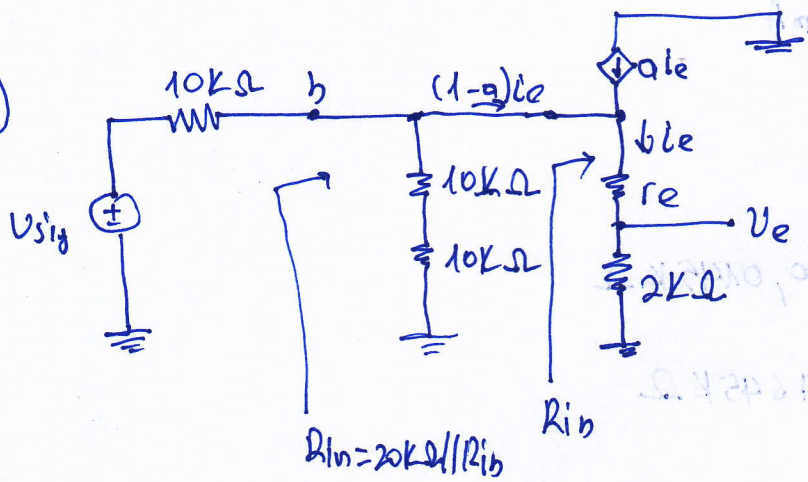
$= \frac{101 \times (10//2) \times (1+0,00145) + 101 \times 0,0145}{1 + 101 \times 0,00145} = 148,3\,K\Omega$

$$\frac{v_b}{v_{sig}} = \frac{R_{in}}{R_{in}+R_{sig}} = \frac{148,3}{1483+10} = 0,937$$

$$\frac{v_o}{v_b} = \frac{v_e}{v_b} = \frac{i_e\left(1+\frac{r_e}{10}\right)(10\|2)}{i_e\left(1+\frac{r_e}{10}\right)(10\|2)+i_e r_e} = \frac{1,00145 \times (10\|2)}{1,00145 \times (10\|2) + 0,0145} = 0,991 \ V/V$$

$$G_{TV} \equiv \frac{v_o}{v_{sig}} = 0,937 \times 0,991 = 0,93 \ \frac{V}{V}$$

γ)



$$R_{in} = 20K\Omega \| R_{ib} = 20K\Omega \| (\beta+1)(R_e+2) = 20\|101 \times 2,0145 = 18,21K\Omega$$

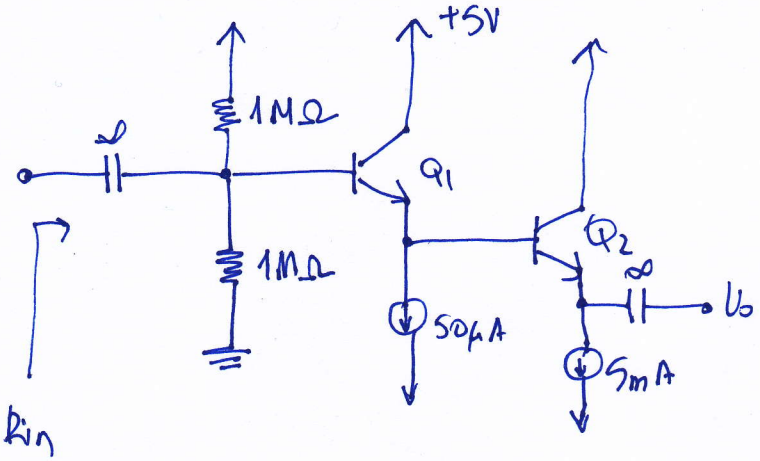
(αναιρεί bootstrapping)

$$\frac{v_b}{v_{sig}} = \frac{R_{in}}{R_{in}+R_{sig}} = \frac{18,21}{28,21} = 0,646 \ V/V$$

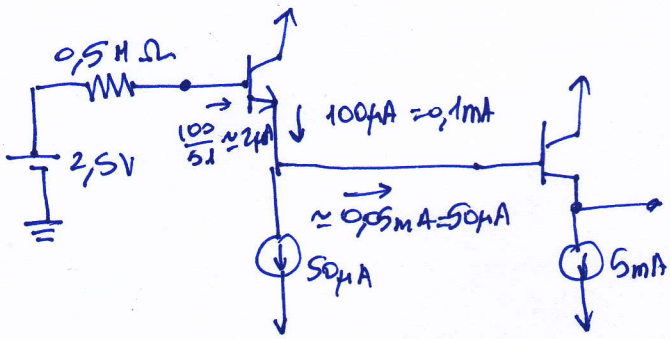
$$\frac{v_o}{v_b} = \frac{2}{2+0,0145} = 0,993$$

$$G_{TV} \equiv \frac{v_o}{v_{sig}} = 0,646 \times 0,993 = 0,64 \ V/V \quad (\text{πολύ μικρότερο κέρδος})$$

Ασκηση 12



α) DC (μέ Thevenin):



$I_{E1} = 0,1\,mA$

$I_{E2} = 5\,mA$

$V_{B1} = 2,5 - 2\mu A \times 0,5M\Omega = 1,5\,V$

$V_{B2} = V_{B1} - 0,7 = 0,8\,V$

β) $R_L = 1k\Omega$

$$\frac{v_o}{v_{b2}} = \frac{R_L}{R_L + r_{e2}}$$

$$r_{e2} = \frac{25mV}{5mA} = 5\Omega$$

$$\frac{v_o}{v_{b2}} = \frac{1000}{1000+5} = 0,995\ V/V$$

$$R_{ib2} = (\beta_2 + 1)(r_{e2} + R_L) = 101 \times 1,005 = 101,5k\Omega$$

γ) $R_{in} = 1M\Omega // 1M\Omega // (\beta+1)(r_{e1} + R_{ib2})$

$$r_{e1} = \frac{V_T}{I_{E1}} = \frac{25mV}{0,1mA} = 250\Omega = 0,25k\Omega$$

$$R_{in} = 0,5M\Omega // [51 \times (0,25 + 101,5)]k\Omega = 0,5M\Omega // 5,2M\Omega = 456k\Omega$$

$$\frac{v_{e1}}{v_{b1}} = \frac{R_{ib}}{R_{in} + r_{e1}} = \frac{101,5}{101,5 + 0,25} = 0,9975\ V/V$$

δ) $\frac{v_{b1}}{v_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} = \frac{456}{456 + 100} = 0,82\ V/V$,

ε) $\frac{v_o}{v_{sig}} = 0,82 \times 0,9975 \times 0,995 = 0,814\ \frac{V}{V}$