VJEŽBE 5

OSNOVE ELEKTRONIKE, ETR, IV SEMESTAR

DOC. DR MILENA ERCEG

ZADATAK 1

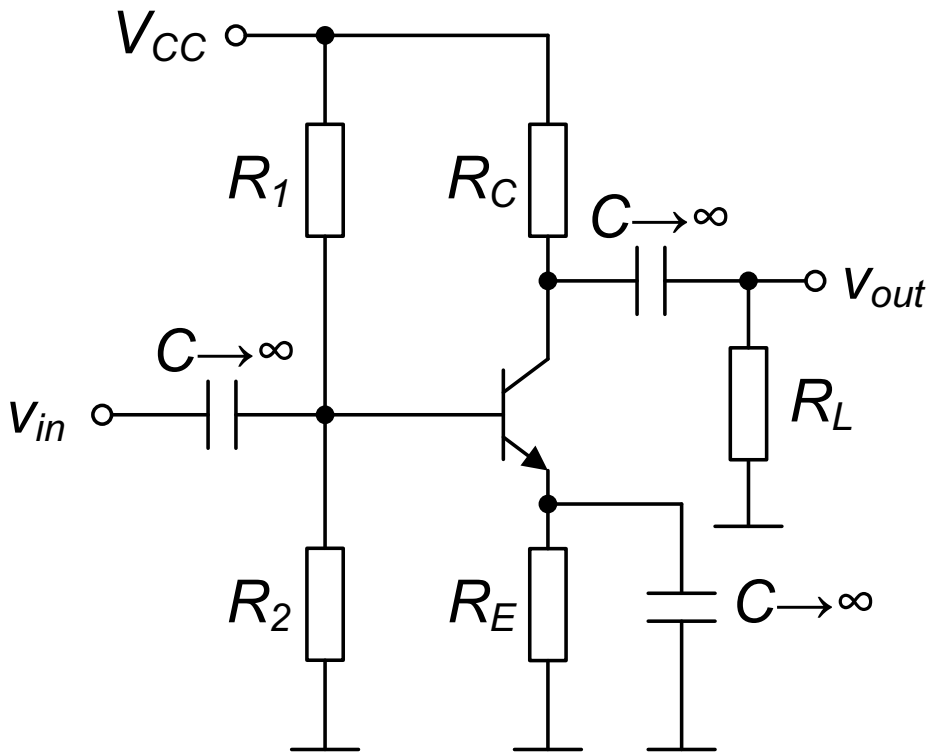
Za kolo prikazano na slici:

a) Izračunati veličine svih jednosmjernih struja i napona,

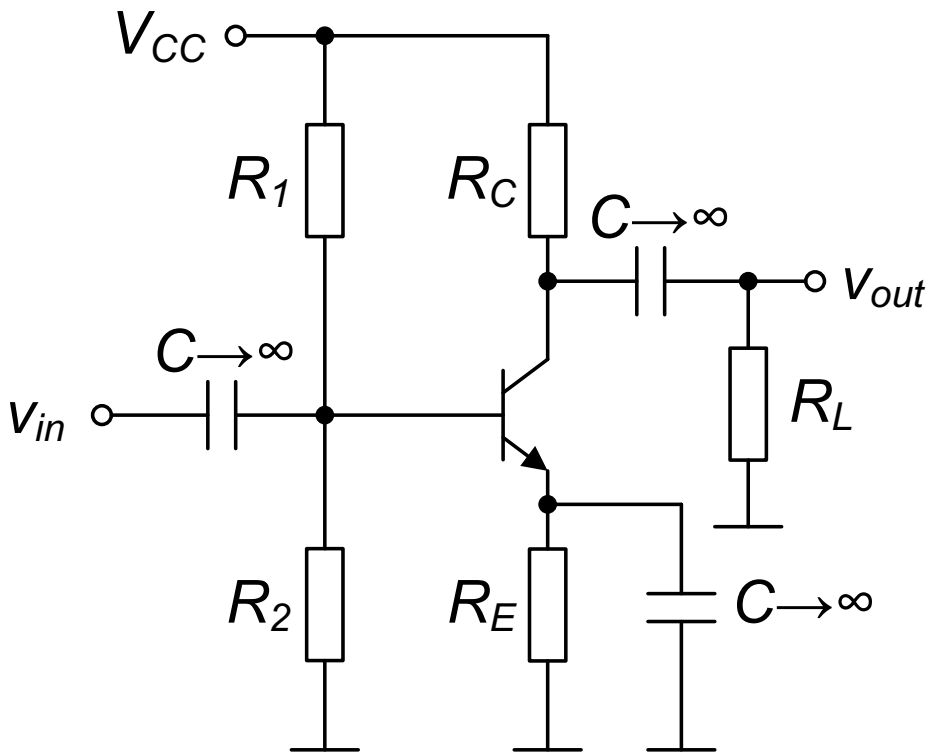
b) Nacrtati jednosmjernu radnu pravu,

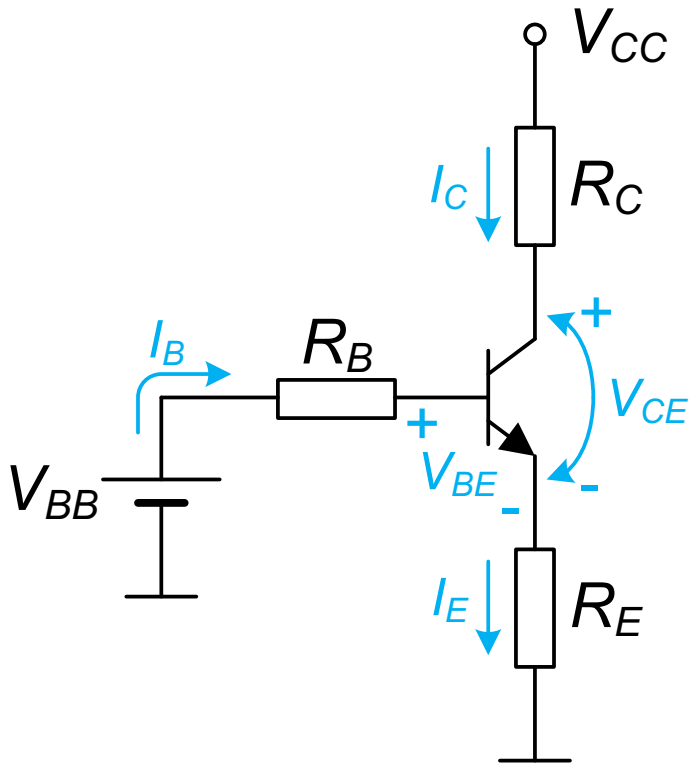
c) Izračunati naponsko pojačanje A_v, strujno pojačanje A_i, ulaznu otpornost R_{in}, izlaznu otpornost R_{out}.

Poznato je: napon napajanja kola V_{CC} = 10 V, otpornosti R_1 = 15 kΩ, R_2 = 5 kΩ, R_C = 2 kΩ, R_E = 950 Ω, otpornost potrošača R_L = 10 kΩ, strujno pojačanje β = 100, napon baza-emitor BJT-a kada provodi V_{BE} = 0.7 V, napon kolektor-emitor BJT-a u zasićenju V_{CES} = 0.2 V, *Early*-jev napon $V_A \rightarrow \infty$ i termički napon $V_T \approx 26$ mV.



ZADATAK 1

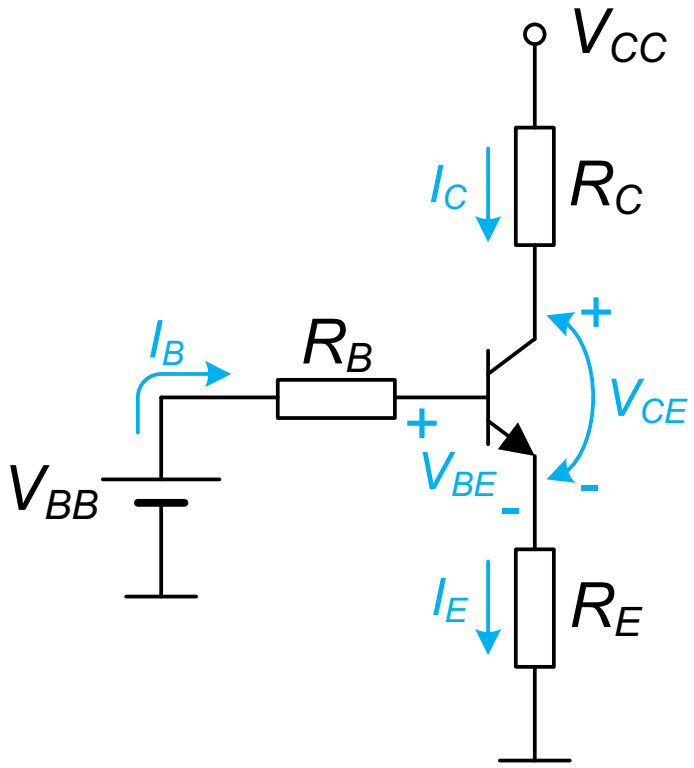




$$R_B = \frac{R_1 R_2}{R_1 + R_2} = 3.75\ \text{k}\Omega$$

$$V_{BB} = \frac{R_2}{R_1 + R_2} V_{CC} = 2.5\ \text{V}$$

ZADATAK 1



Pretpostavka: BJT u DAR-u

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

$$\Longrightarrow I_B = \frac{V_{BB} - V_{BE}}{R_B + (\beta + 1)R_E} = 18.05\ \mu\text{A}$$

$$I_C = \beta I_B = 1.805\ \text{mA}$$

$$I_E = (\beta + 1) I_B = 1.823\ \text{mA}$$

$$V_{CE} = V_{CC} - R_C I_C - R_E I_E = 4.658\ \text{V} > V_{CES}$$

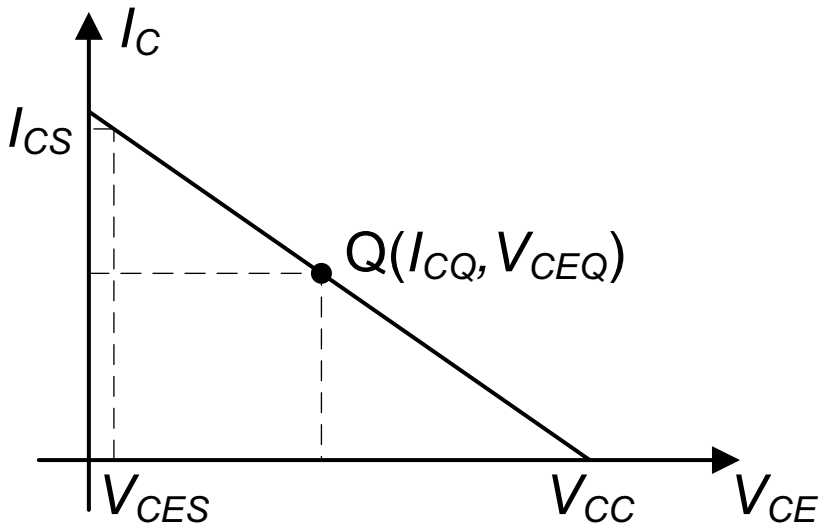
Slijedi da je pretpostavka o DAR-u tačna.

ZADATAK 1

$$V_{CE} = V_{CC} - R_C I_C - R_E I_E$$

Jednačina jednosmjerne radne prave data je sljedećim izrazom:

$$V_{CE} = V_{CC} - R_C I_C - \frac{\beta + 1}{\beta} R_E I_C = V_{CC} - \left(R_C + \frac{\beta + 1}{\beta} R_E\right) I_C$$



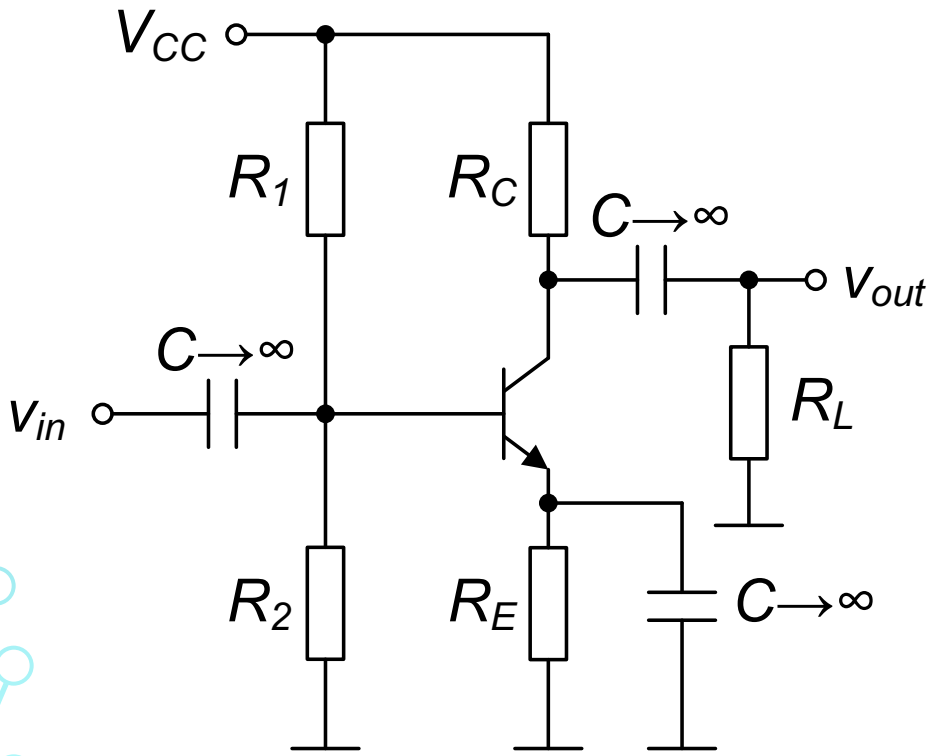
$I_{CQ} = 1.805$ mA, $V_{CEQ} = 4.658$ V

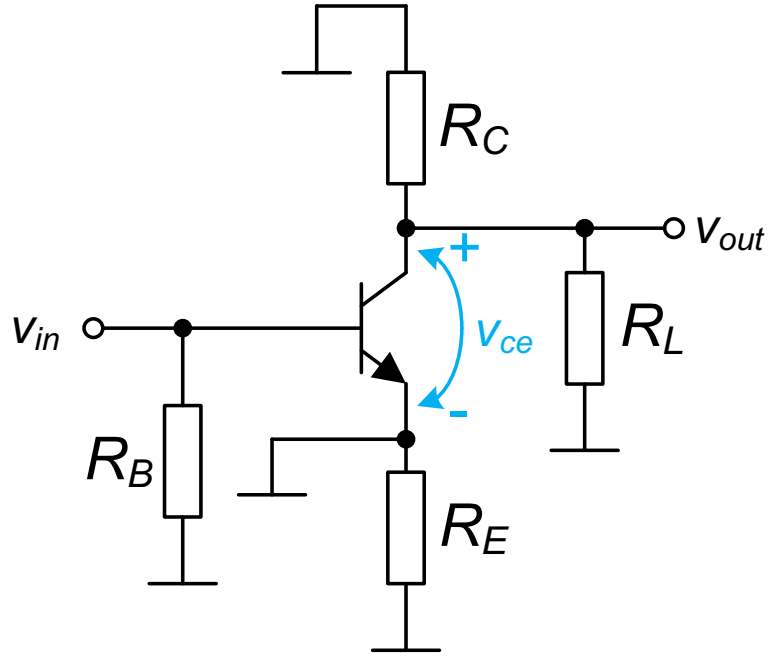
$$I_{CS} = \frac{V_{CC} - V_{CES}}{R_C + \frac{\beta + 1}{\beta} R_E} = 3.31 \text{ mA}$$

Maksimalna vrijednost AC komponente kolektorske struje, da ne bi došlo do izobličenja je:

$$i_{cmax} = I_{CS} - I_{CQ} = 1.505 \text{ mA}$$

ZADATAK 1

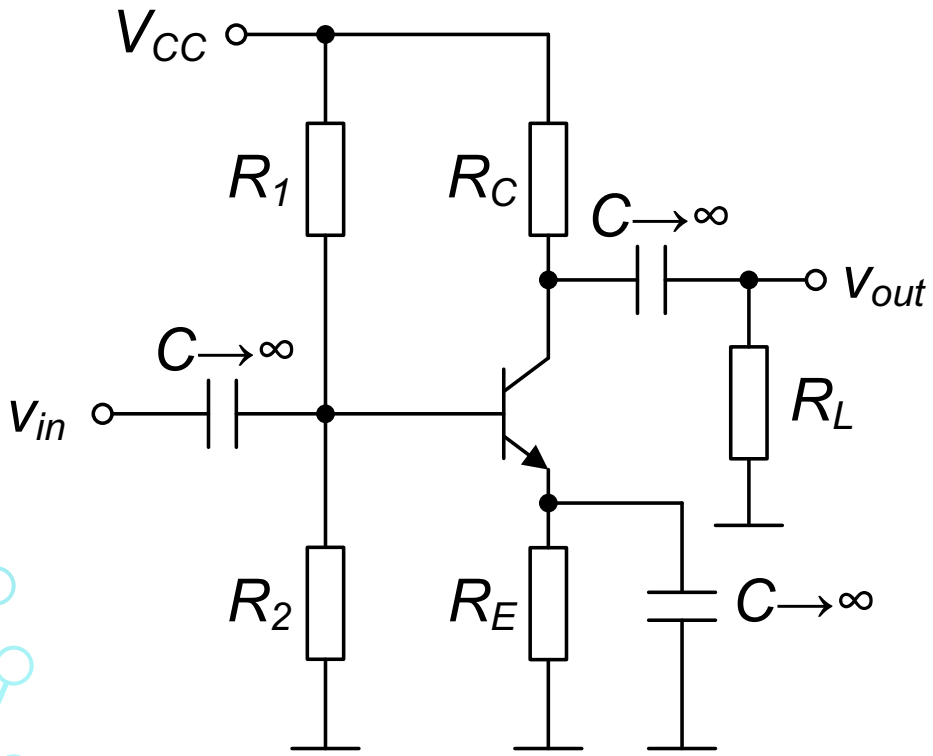




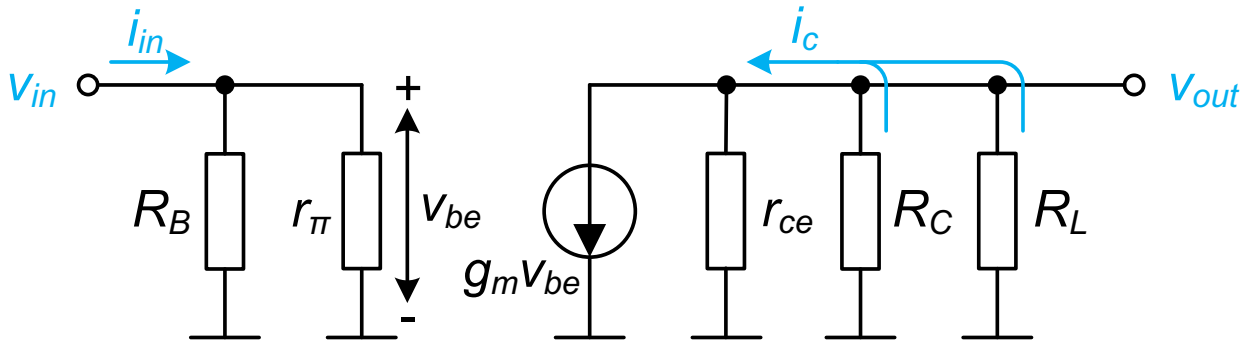
Na slici je prikazano ekvivalentno kolo za AC analizu. Maksimalna vrijednost AC komponente napona kolektor-emitor iznosi:

$$v_{cemax} = v_{outmax} = \frac{R_C R_L}{R_C + R_L} i_{cmax} = 2.5\ \text{V}$$

ZADATAK 1



Model za male signale



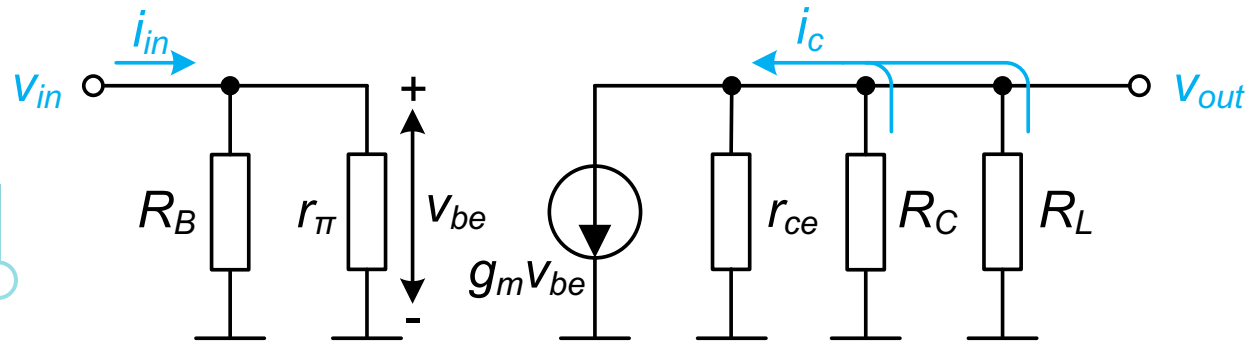
$$R_B = \frac{R_1 R_2}{R_1 + R_2} = 3.75\ \text{k}\Omega$$

$$g_m = \frac{I_C}{V_T} = 69.42\ \text{mS}$$

$$r_\pi = \frac{\beta}{g_m} = 1.44\ \text{k}\Omega$$

$$r_{ce} = \frac{V_A}{I_C} \longrightarrow \infty \quad \text{(predstavlja prekid u kolu)}$$

ZADATAK 1



$$v_{be} = v_{in}$$

$$g_m v_{in} + \frac{v_{out}}{R_C} + \frac{v_{out}}{R_L} = 0$$

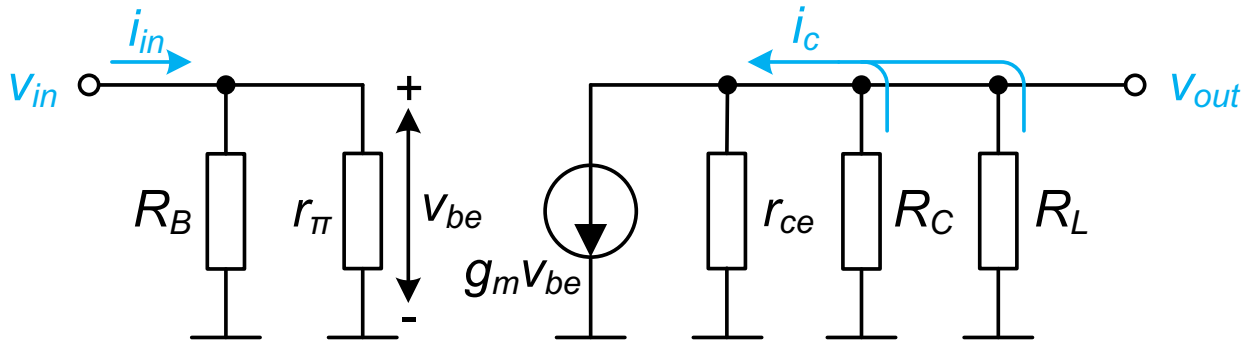
$$A_v = \frac{v_{out}}{v_{in}} = -g_m \frac{R_C R_L}{R_C + R_L} = -115.7$$

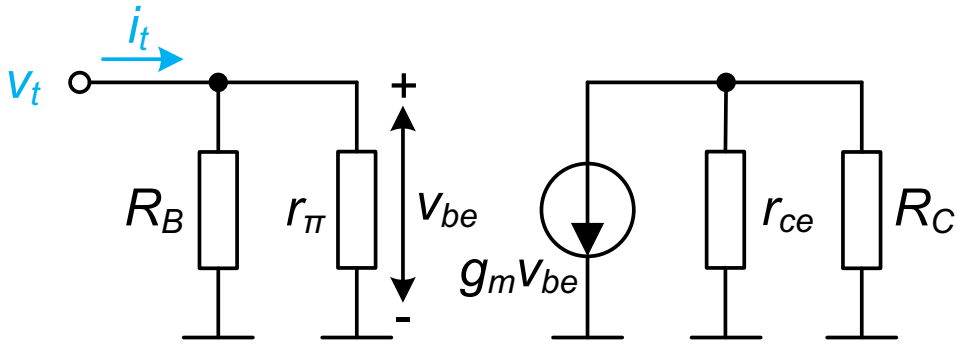
$$i_{in} = \frac{v_{in}}{R_B} + \frac{v_{in}}{r_\pi}$$

$$i_{out} = g_m v_{be} = g_m v_{in}$$

$$A_i = \frac{i_{out}}{i_{in}} = g_m \frac{R_B r_\pi}{R_B + r_\pi} = 72.25$$

ZADATAK 1

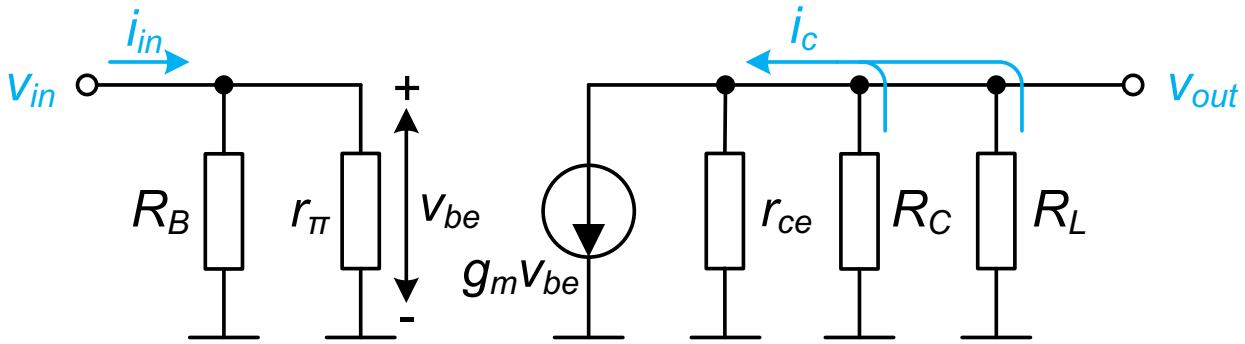


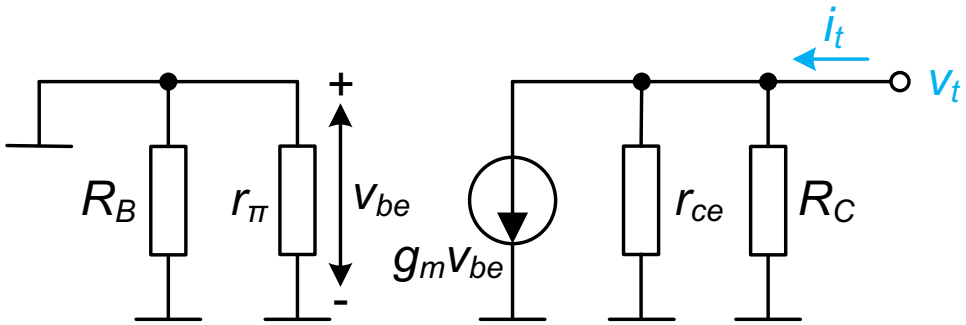


$$R_{in} = \frac{v_t}{i_t} = \frac{R_B r_\pi}{R_B + r_\pi} = 1.04\ \text{k}\Omega$$

Ulazna otpornost kola se računa tako što se na ulaz kola veže test generator, iz kola se isključi potrošač, dok se svi nezavisni naponski izvori kratko spajaju, a nezavisni strujni izvori prekidaju.

ZADATAK 1



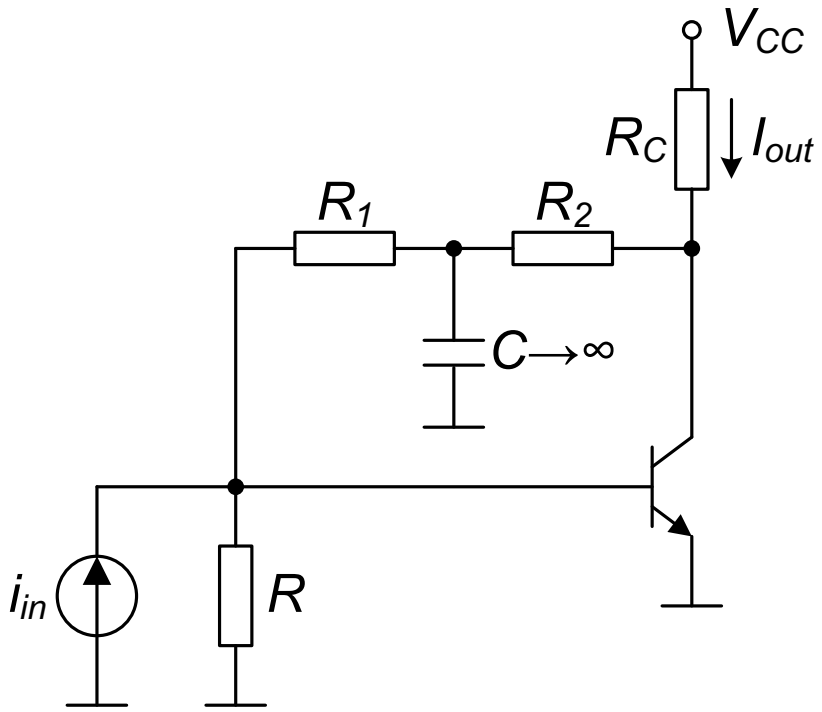


$$R_{out} = \frac{v_t}{i_t} = R_C = 2\ \text{k}\Omega$$

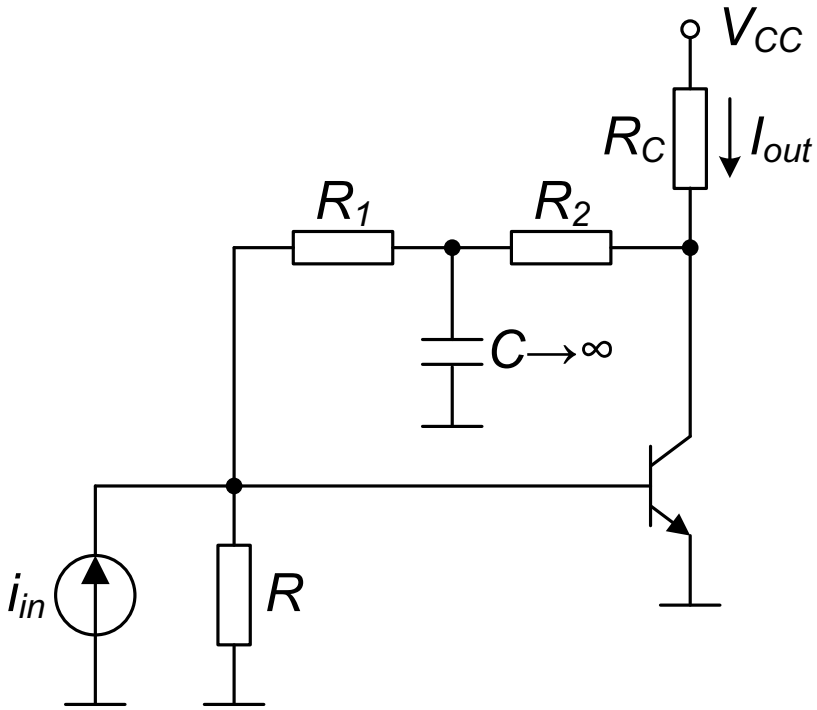
Izlazna otpornost kola se računa tako što se na izlaz kola veže test generator, iz kola se isključi potrošač, dok se svi nezavisni naponski izvori kratko spajaju, a nezavisni strujni izvori prekidaju.

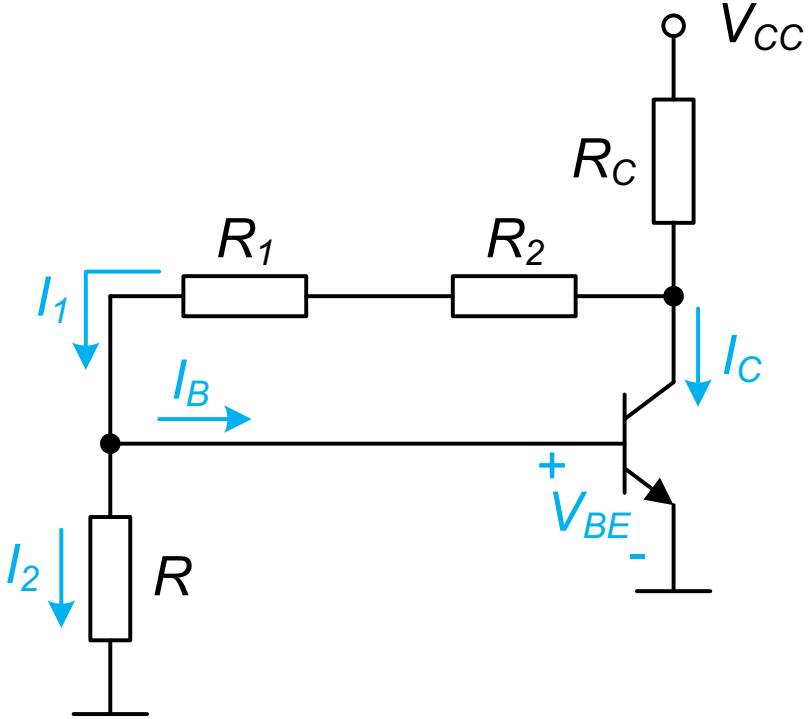
ZADATAK 2

Za kolo prikazano na slici odrediti strujno pojačanje A_i. Poznato je: napon napajanja kola V_{CC} = 10 V, otpornosti $R_1 = R_2 = 20$ kΩ, $R = 100$ kΩ, $R_C = 1$ kΩ, strujno pojačanje $\beta = 50$, napon baza-emitor BJT-a kada provodi $V_{BE} = 0.7$ V, napon kolektor-emitor BJT-a u zasićenju $V_{CES} = 0.2$ V, *Early*-jev napon $V_A \rightarrow \infty$ i termički napon $V_T \approx 26$ mV.



ZADATAK 2





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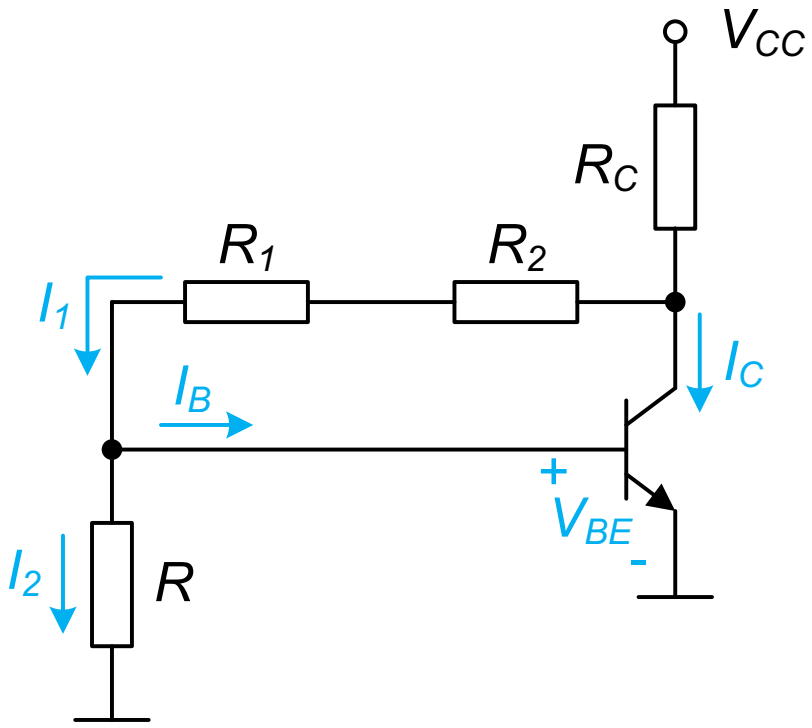


Pretpostavka: BJT u DAR-u

$$I_2 = \frac{V_{BE}}{R} = 7\ \mu\text{A}$$

$$V_{CC} - R_C(I_1 + I_C) - (R_1 + R_2)I_1 - V_{BE} = 0$$

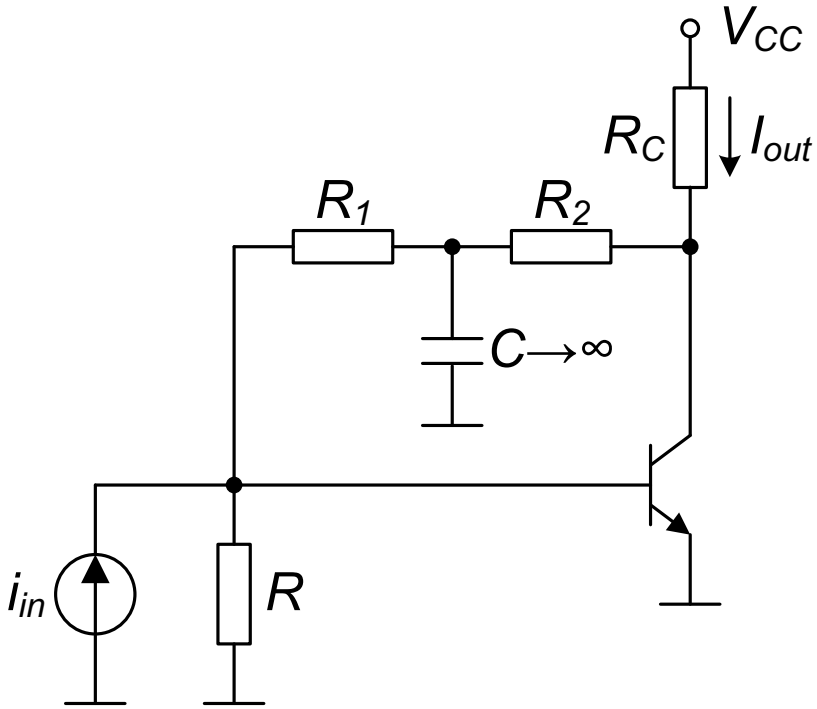
$$I_1 = I_B + I_2$$

$$I_B = \frac{V_{CC} - (R_1 + R_2 + R_C)I_2 - V_{BE}}{(\beta + 1)R_C + R_1 + R_2} = 99.04\ \mu\text{A}$$

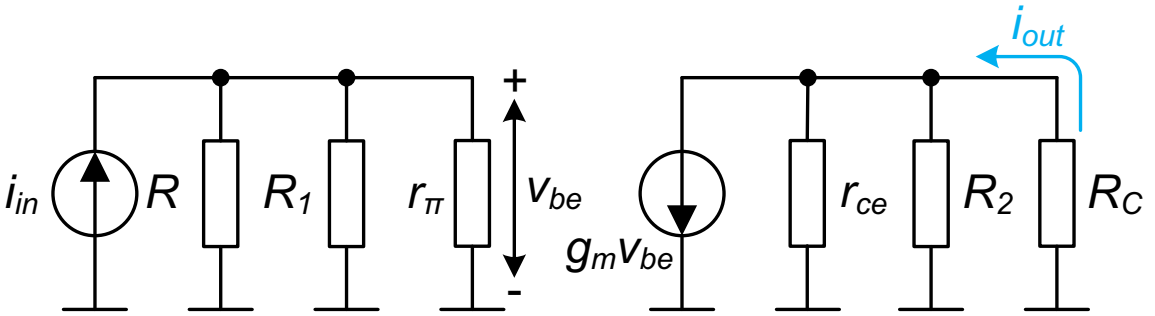
$$V_{CE} = V_{CC} - R_C(I_1 + I_C) = V_{CC} - R_C[I_2 + (\beta + 1)I_B] = 4.94\ \text{V} > V_{CES}$$

Slijedi da je pretpostavka o DAR-u tačna.

ZADATAK 2



Model za male signale

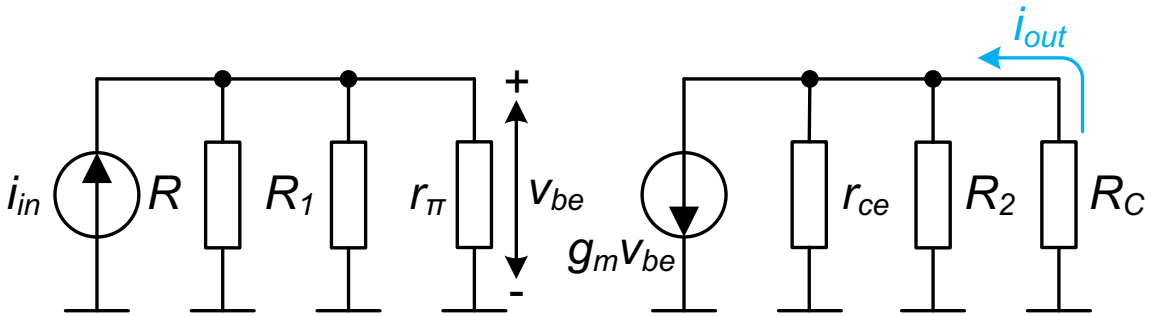


$$g_m = \frac{I_C}{V_T} = 190 \text{ mS}$$

$$r_\pi = \frac{\beta}{g_m} = 262.5\ \Omega$$

$$r_{ce} = \frac{V_A}{I_C} \longrightarrow \infty \quad \text{(predstavlja prekid u kolu)}$$

ZADATAK 2



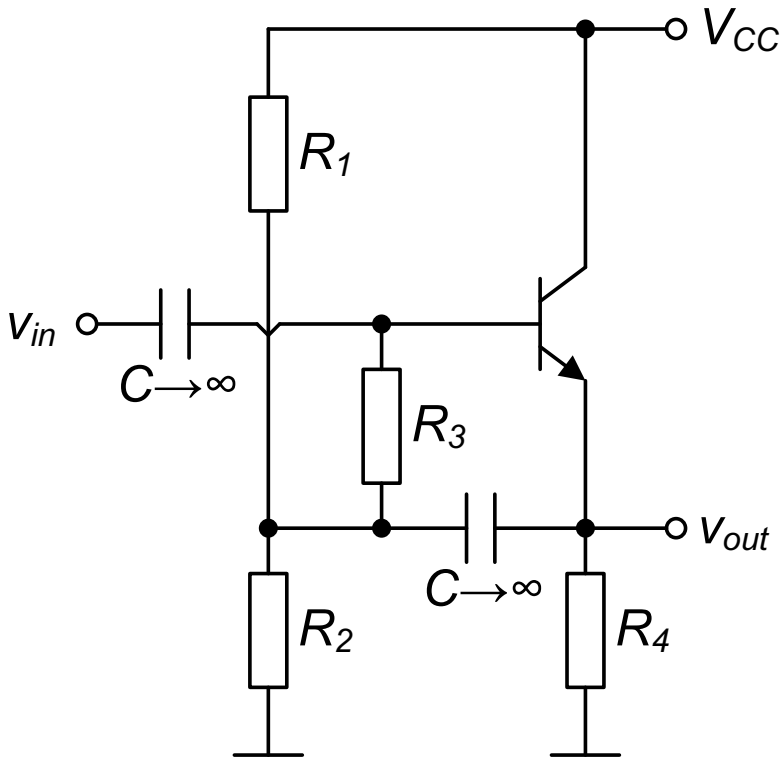
$$i_{in} = \left(\frac{1}{R_1} + \frac{1}{R} + \frac{1}{r_\pi}\right) v_{be}$$

$$i_{out} = \frac{R_2}{R_2 + R_C} g_m v_{be}$$

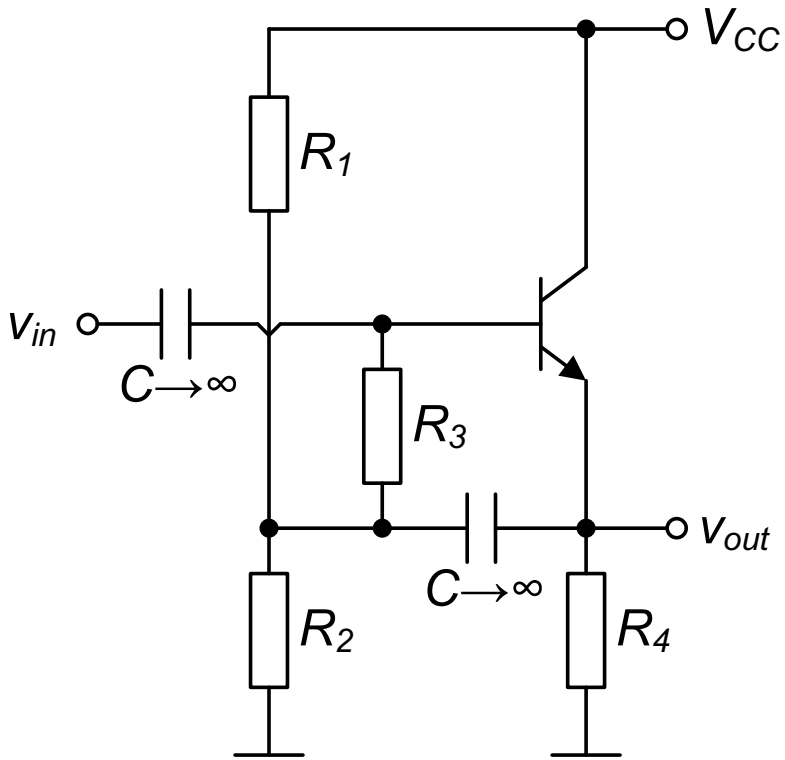
$$A_i = \frac{i_{out}}{i_{in}} = g_m \frac{\frac{R_2}{R_2 + R_C}}{\frac{1}{R_1} + \frac{1}{R} + \frac{1}{r_\pi}} = 46.76$$

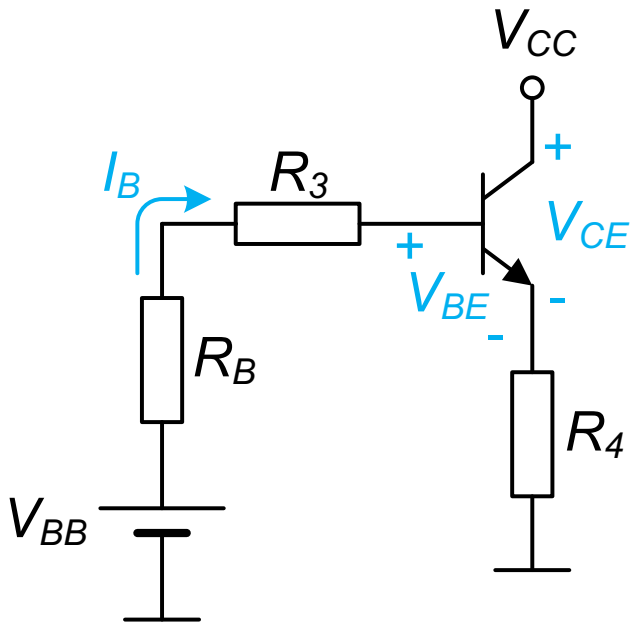
ZADATAK 3

Za kolo prikazano na slici odrediti naponsko pojačanje A_v i ulaznu otpornost kola R_{in}. Poznato je: napon napajanja kola $V_{CC} = 10$ V, otpornosti $R_1 = R_2 = 12$ kΩ, $R_3 = 10$ kΩ, $R_4 = 1$ kΩ, strujno pojačanje $\beta = 100$, napon baza-emitor BJT-a kada provodi $V_{BE} = 0.7$ V, napon kolektor-emitor BJT-a u zasićenju $V_{CES} = 0.2$ V, *Early*-jev napon $V_A \to \infty$ i termički napon $V_T \approx 26$ mV.



ZADATAK 3

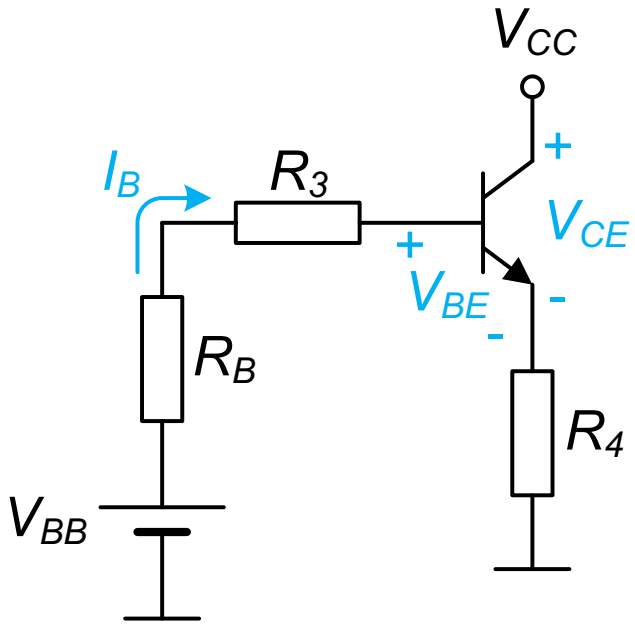




$$R_B = \frac{R_1 R_2}{R_1 + R_2} = 6\ \text{k}\Omega$$

$$V_{BB} = \frac{R_2}{R_1 + R_2} V_{CC} = 5\ \text{V}$$

ZADATAK 3



Pretpostavka: BJT u DAR-u

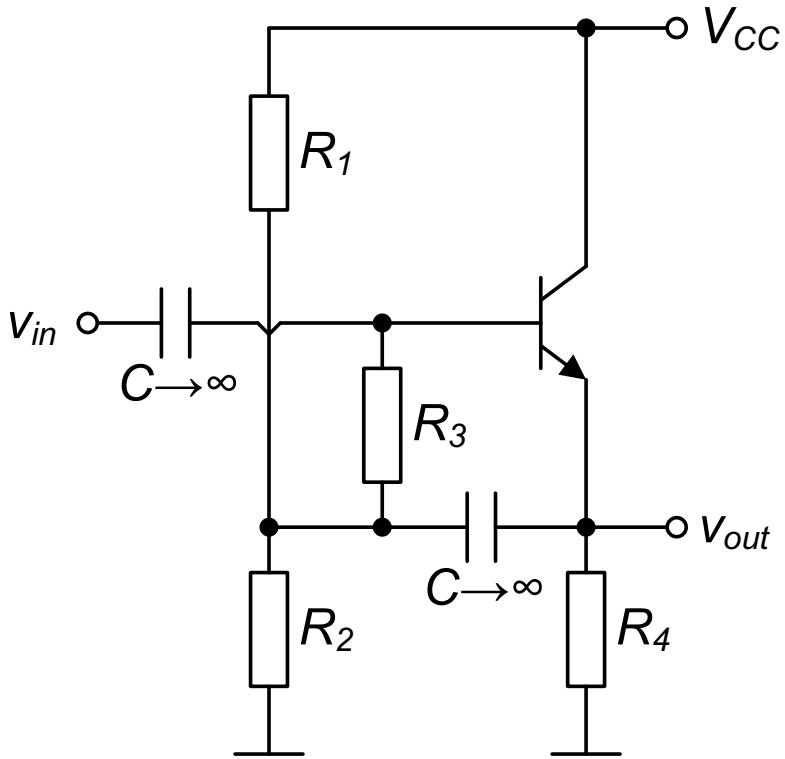
$$V_{BB} - (R_B + R_3)I_B - V_{BE} - (\beta + 1)R_4 I_B = 0$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B + R_3 + (\beta + 1)R_4} = 36.75\ \mu\text{A}$$

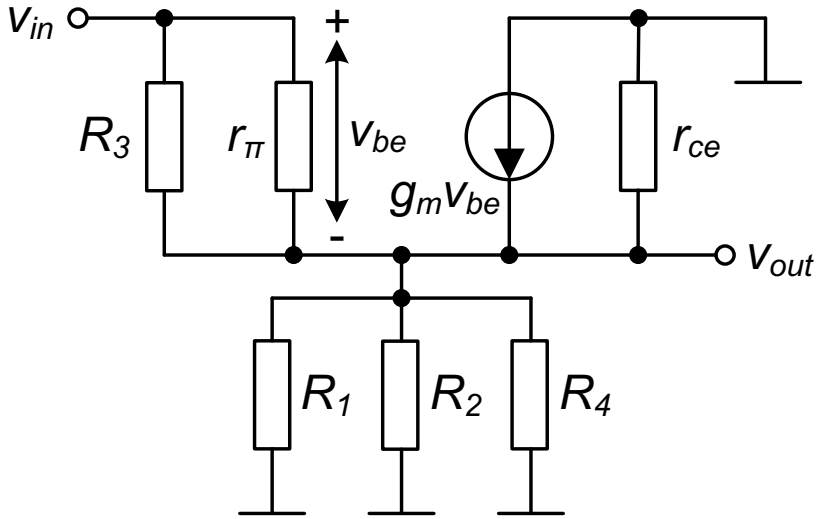
$$V_{CE} = V_{CC} - (\beta + 1)R_4 I_B = 6.29\ \text{V} > V_{CES}$$

Slijedi da je pretpostavka o DAR-u BJT-a tačna.

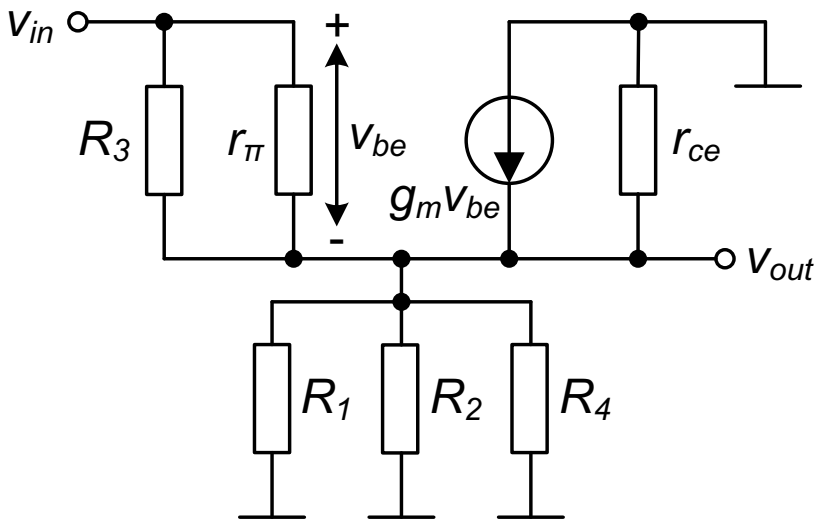
ZADATAK 3



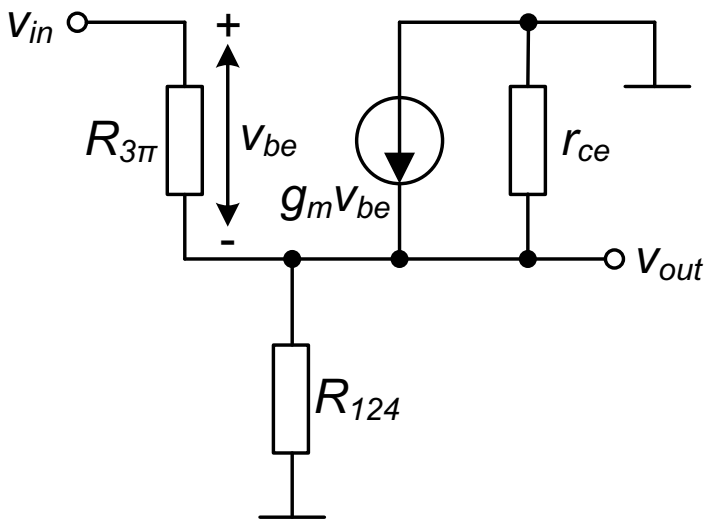
Model za male signale



ZADATAK 3



$\Leftrightarrow$



$$R_{3\pi} = R_3 || r_\pi = 660.7\ \Omega$$

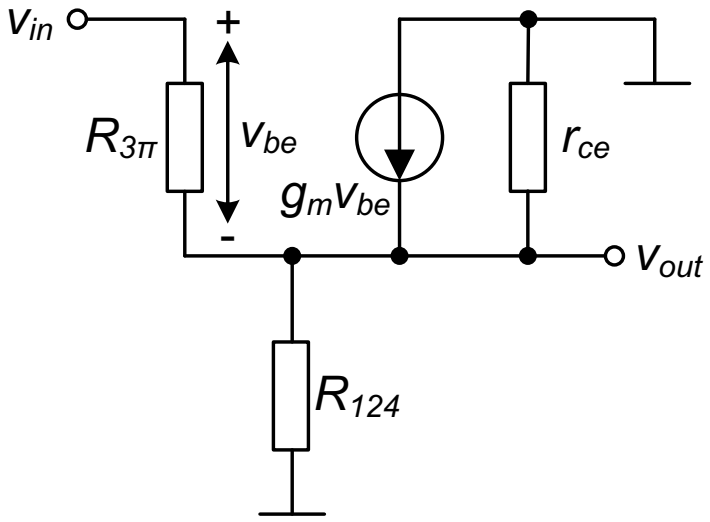
$$R_{124} = R_1 || R_2 || R_4 = 857\ \Omega$$

$$g_m = \frac{I_C}{V_T} = 141\ \text{mS}$$

$$r_\pi = \frac{\beta}{g_m} = 707.5\ \Omega$$

$$r_{ce} = \frac{V_A}{I_C} \longrightarrow \infty$$

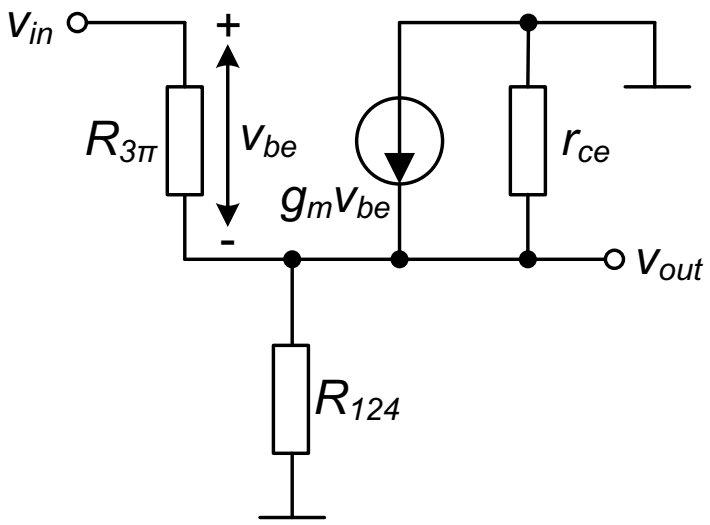
ZADATAK 3

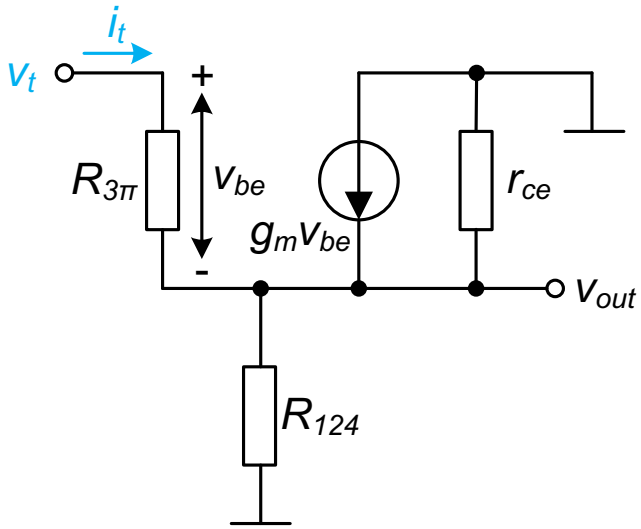


$$\frac{v_{in} - v_{out}}{R_{3\pi}} + g_m(v_{in} - v_{out}) = \frac{v_{out}}{R_{124}}$$

$$A_v = \frac{v_{out}}{v_{in}} = \frac{(g_m R_{3\pi} + 1)R_{124}}{(g_m R_{3\pi} + 1)R_{124} + R_{3\pi}} = 0.992$$

ZADATAK 3



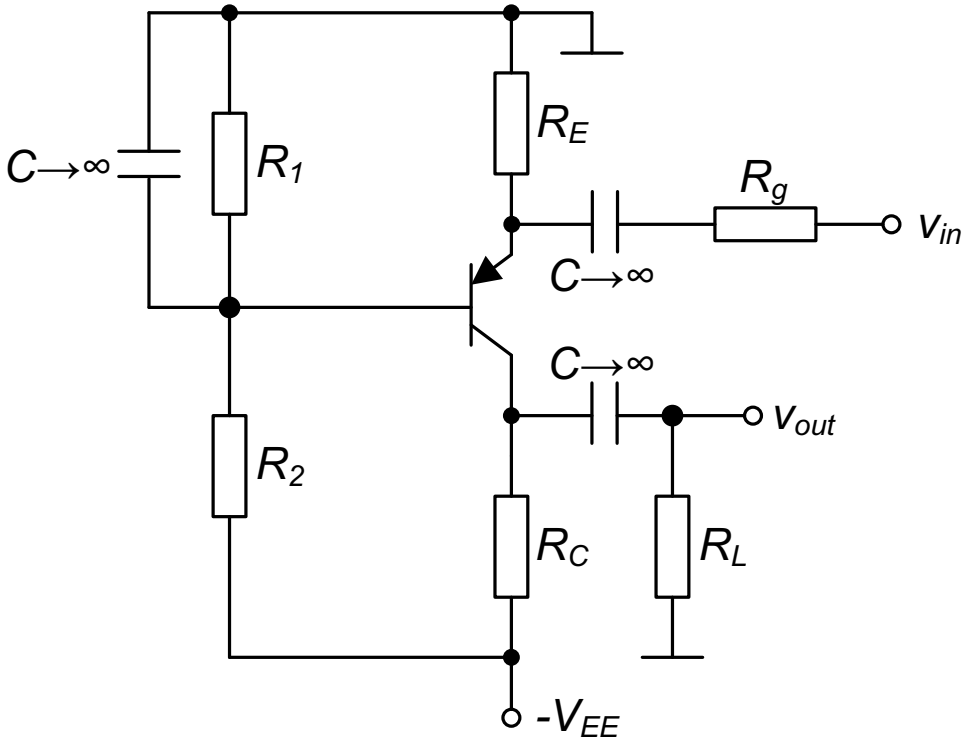


$$i_t = \frac{v_t - v_{out}}{R_{3\pi}} = \frac{v_t}{R_{3\pi}}\left(1 - \frac{v_{out}}{v_t}\right) = \frac{v_t}{R_{3\pi}}(1 - A_v)$$

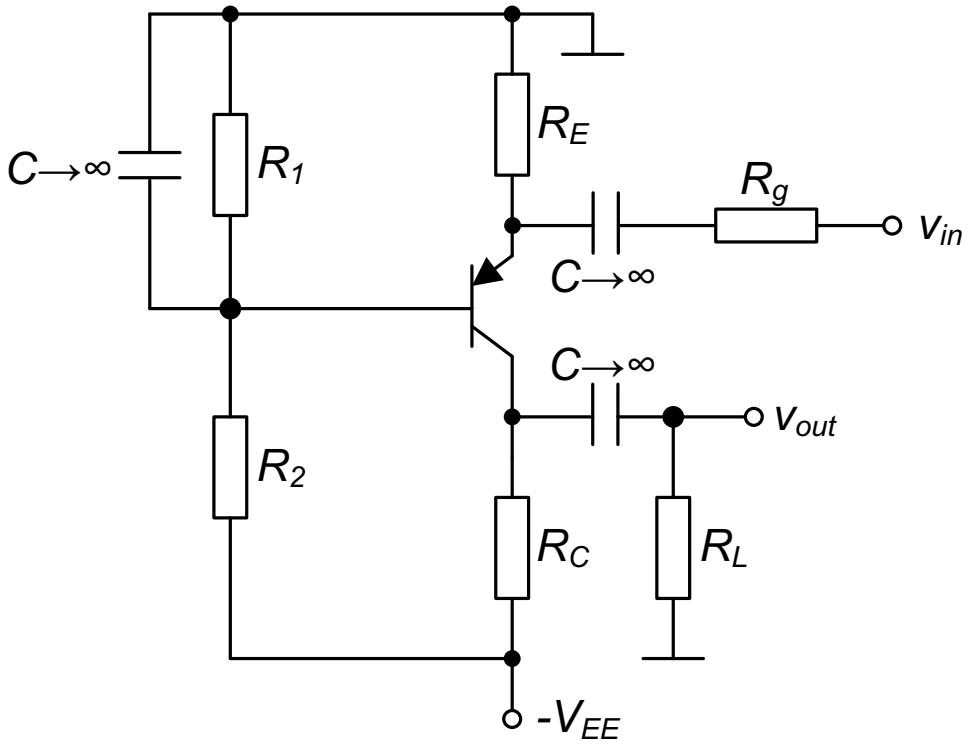
$$R_{in} = \frac{v_t}{i_t} = \frac{R_{3\pi}}{1 - A_v} = 82.6\ \text{k}\Omega$$

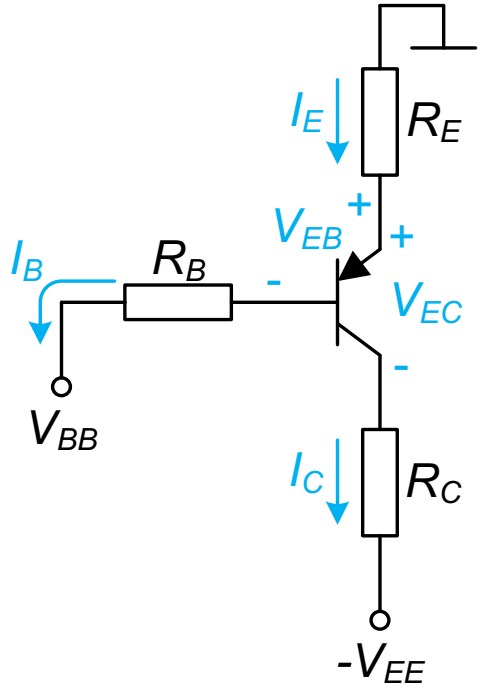
ZADATAK 4

Za kolo prikazano na slici odrediti naponsko pojačanje A_v i ulaznu otpornost kola R_{in}. Poznato je: napon napajanja kola $V_{EE} = 10$ V, otpornosti $R_1 = 10$ kΩ, $R_2 = 50$ kΩ, $R_C = 8$ kΩ, $R_E = 1.2$ kΩ, otpornost potrošača $R_L = 30$ kΩ, unutrašnja otpornost generatora $R_g = 100$ Ω, strujno pojačanje $\beta = 99$, napon emitor-baza BJT-a kada provodi $V_{EB} = 0.7$ V, napon emitor-kolektor BJT-a u zasićenju $V_{ECS} = 0.2$ V, *Early*-jev napon $V_A \to \infty$ i termički napon $V_T \approx 26$ mV.



ZADATAK 4

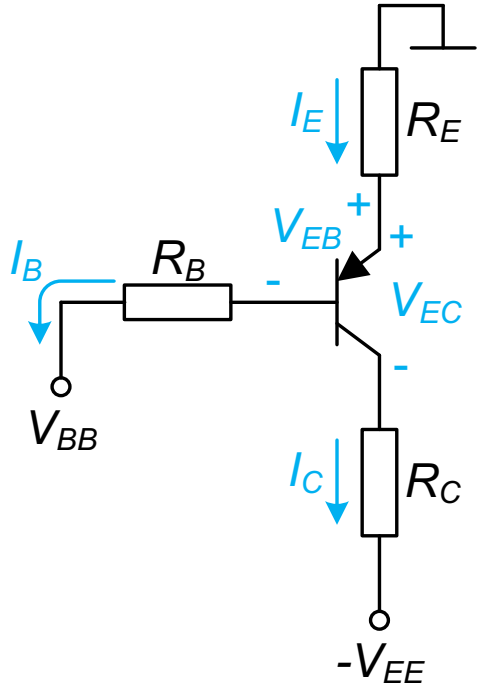




$$R_B = \frac{R_1 R_2}{R_1 + R_2} = 8.33\ \text{k}\Omega$$

$$V_{BB} = -\frac{R_1}{R_1 + R_2} V_{EE} = -1.67\ \text{V}$$

ZADATAK 4



Pretpostavka: BJT u DAR-u

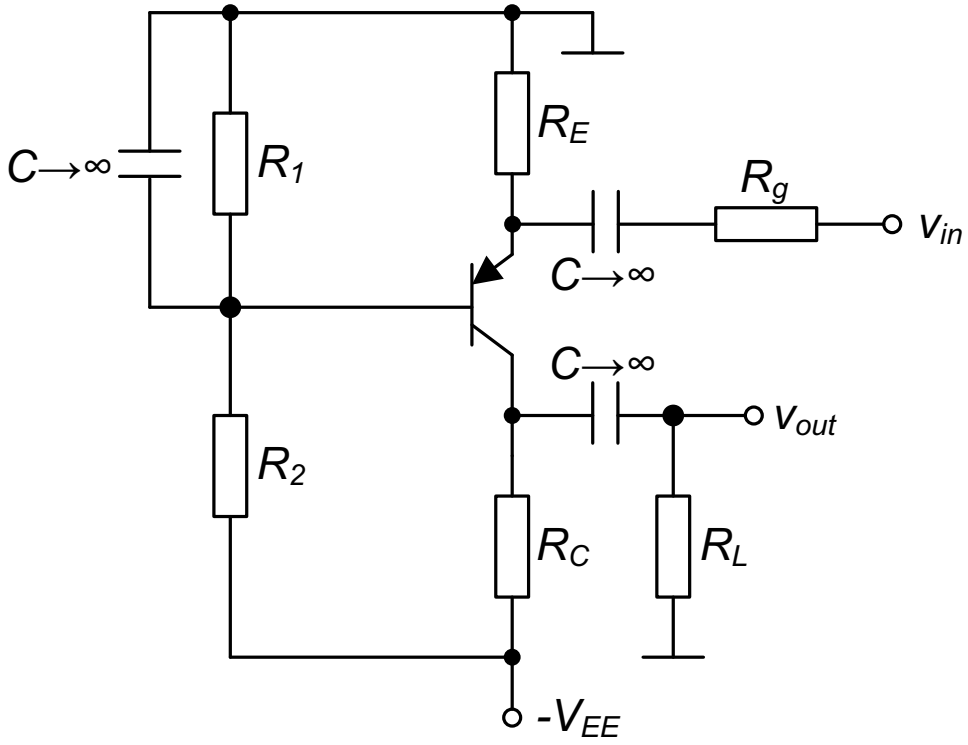
$$V_{BB} + R_B I_B + V_{EB} + R_E I_E = 0$$

$$I_B = \frac{-V_{BB} - V_{EB}}{R_B + (\beta + 1)R_E} = 7.56\ \mu\text{A}$$

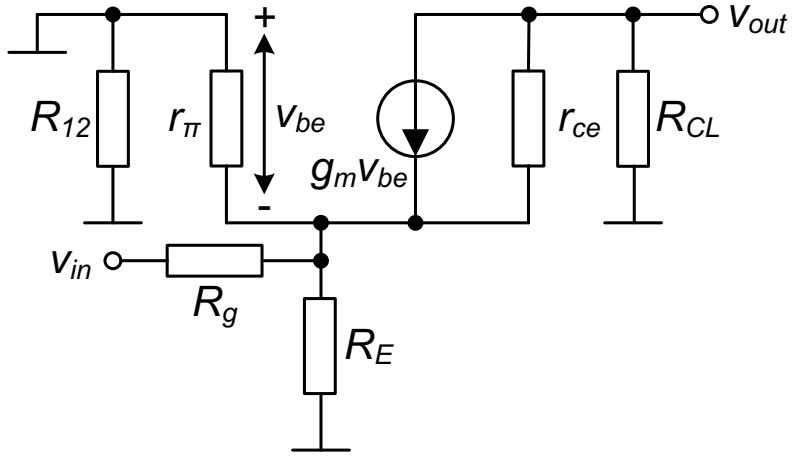
$$V_{EC} = -R_E I_E - R_C I_C + V_{EE} = 3.11\ \text{V} > V_{ECS}$$

Slijedi da je pretpostavka o DAR-u tačna.

ZADATAK 4



Model za male signale



$$g_m = \frac{I_C}{V_T} = 28.79\ \text{mS}$$

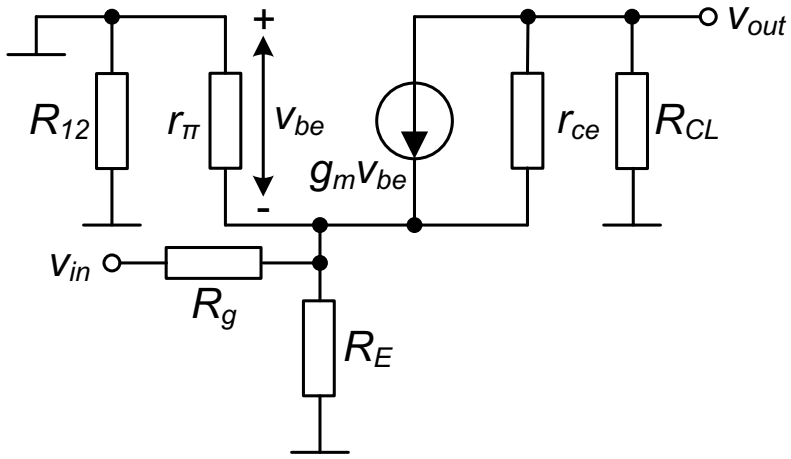
$$r_\pi = \frac{\beta}{g_m} = 3.44\ \text{k}\Omega$$

$$r_{ce} = \frac{V_A}{I_C} \longrightarrow \infty$$

$$R_{CL} = R_C||R_L = 6.32\ \text{k}\Omega$$

$$R_{12} = R_1||R_2 = 8.33\ \text{k}\Omega$$

ZADATAK 4

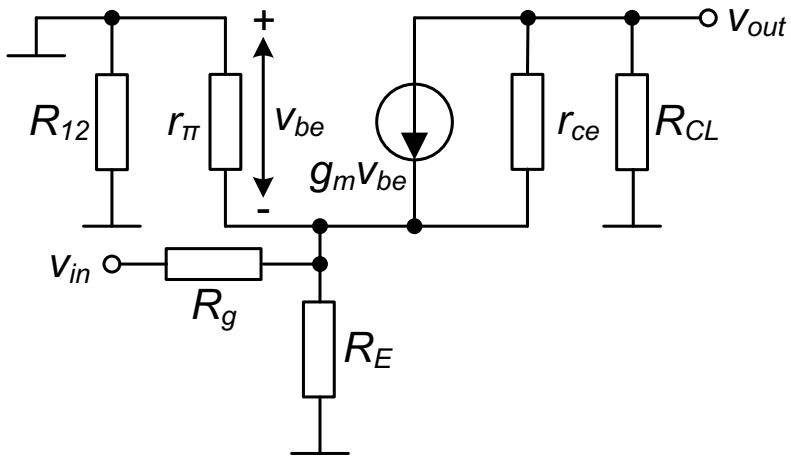


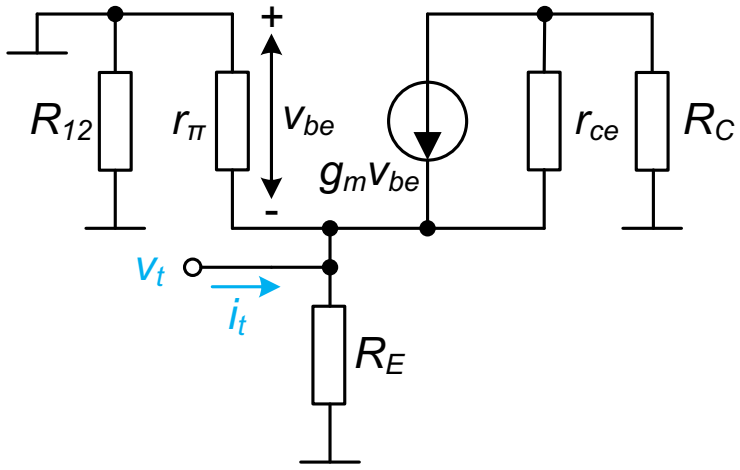
$$\frac{v_{be}}{r_\pi} + g_m v_{be} + \frac{v_{in} + v_{be}}{R_g} + \frac{v_{be}}{R_E} = 0$$

$$g_m v_{be} + \frac{v_{out}}{R_{CL}} = 0$$

$$A_v = \frac{v_{out}}{v_{in}} = R_{CL} \frac{\beta R_E}{R_E[r_\pi + (\beta + 1)R_g] + r_\pi R_g} = 45.55$$

ZADATAK 4





$$i_t = \frac{v_t}{R_E} + g_m v_t + \frac{v_t}{r_\pi}$$

$$R_{in} = \frac{v_t}{i_t} = \frac{r_\pi R_E}{r_\pi + (\beta + 1) R_E} = 33.43\ \Omega$$

Napomena: Prilikom kratkog spajanja nezavisnog naponskog generatora v_{in}, iz kola se isključuje i otpornost R_g jer predstavlja unutrašnju otpornost nezavisnog naponskog generatora v_{in}.