VJEŽBE 3

OSNOVE ELEKTRONIKE, ETR, IV SEMESTAR

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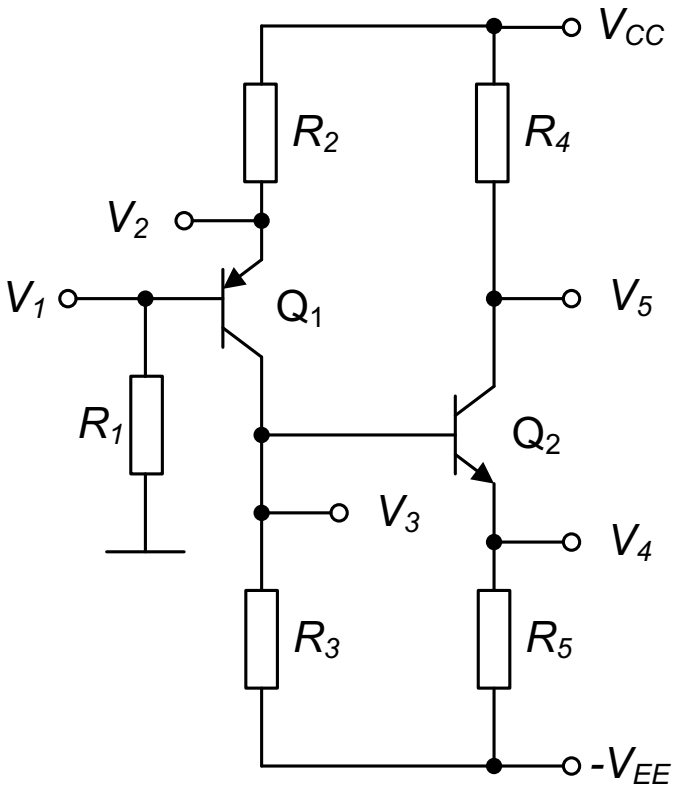
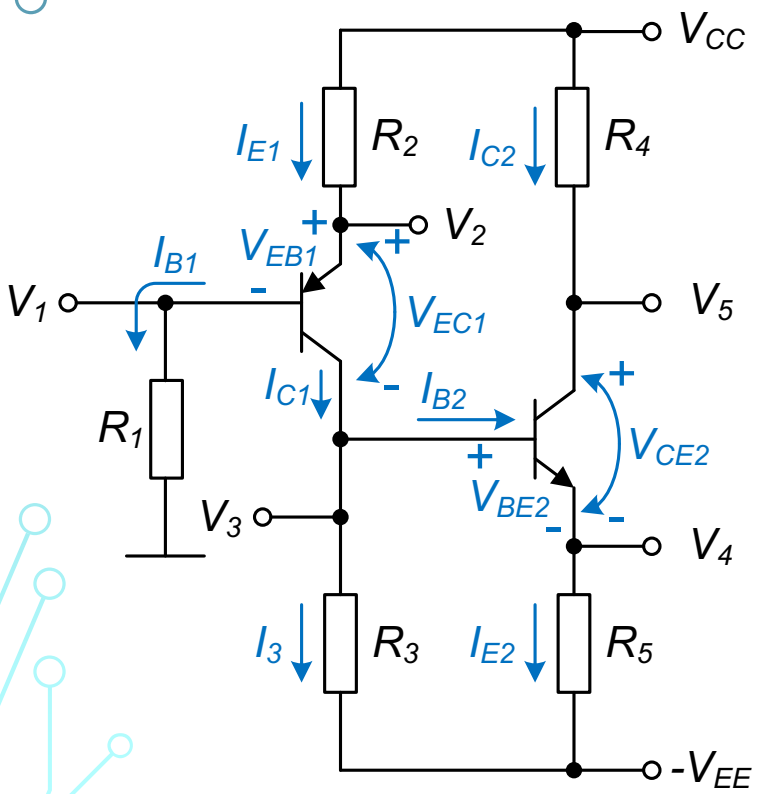
ZADATAK 1

Za kolo prikazano na slici odrediti vrijednosti napona V_1, V_2, V_3, V_4 i V_5. Poznato je: $V_{CC}=V_{EE}=10$ V, $V_{EB1}=V_{BE2}=0.7$ V, $V_{ECS1}=V_{CES2}=0.2$ V, $\beta=100$, $R_1=100$ kΩ, $R_2=9.1$ kΩ, $R_3=9.1$ kΩ, $R_4=5.1$ kΩ i $R_5=4.3$ kΩ.



ZADATAK 1



$$V_{CC} - R_2 I_{E1} - V_{EB1} - R_1 I_{B1} = 0$$

$$V_{CC} - R_2(\beta + 1) I_{B1} - V_{EB1} - R_1 I_{B1} = 0$$

$$I_{B1} = \frac{V_{CC} - V_{EB1}}{(\beta + 1)R_2 + R_1} = 9.125\ \mu\text{A}$$

$$I_{C1} = \beta I_{B1} = 0.913\ \text{mA}$$

$$I_{E1} = (\beta + 1) I_{B1} = 0.922\ \text{mA}$$

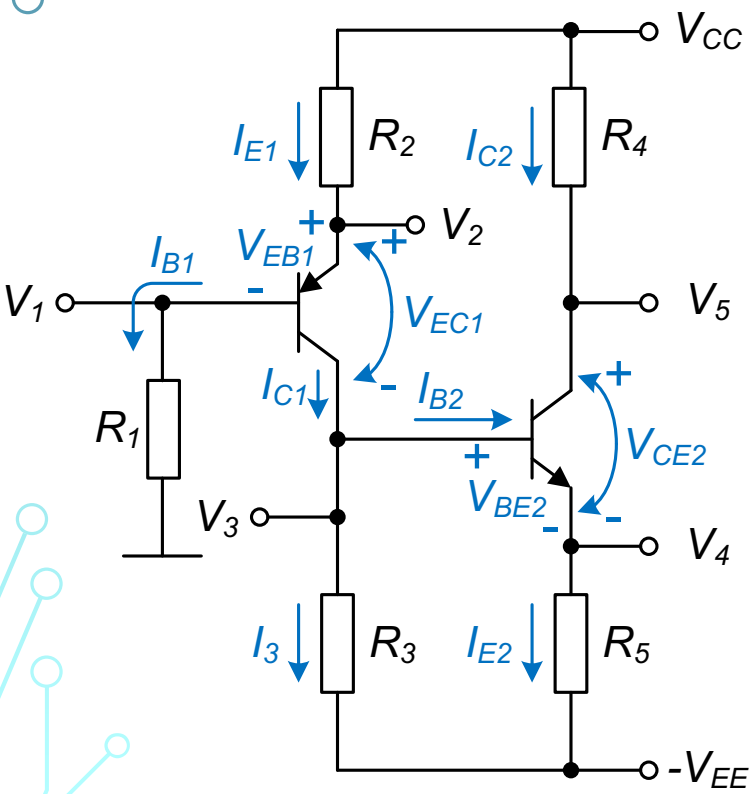
$$V_{BE2} + R_5 I_{E2} - R_3 I_3 = 0$$

$$V_{BE2} + R_5(\beta + 1) I_{B2} - R_3(I_{C1} - I_{B2}) = 0$$

$$V_{BE2} - R_3 I_{C1} + [(\beta + 1)R_5 + R_3] I_{B2} = 0$$

$$I_{B2} = \frac{-V_{BE2} + R_3 I_{C1}}{(\beta + 1)R_5 + R_3} = 17.14\ \mu\text{A}$$

ZADATAK 1



$$I_{C2} = \beta I_{B2} = 1.714\ \text{mA}$$

$$I_{E2} = (\beta + 1) I_{B2} = 1.732\ \text{mA}$$

$$V_{EC1} = V_{CC} - R_2 I_{E1} - R_3 I_3 + V_{EE} = 3.466\ \text{V} > V_{ECS1} = 0.2\ \text{V}$$

$$V_{CE2} = V_{CC} - R_4 I_{C2} - R_5 I_{E2} + V_{EE} = 3.811\ \text{V} > V_{CES2} = 0.2\ \text{V}$$

Slijedi da je pretpostavka o DAR-u tačna.

$$V_1 = R_1 I_{B1} = 0.913\ \text{V}$$

$$V_2 = V_{CC} - R_2 I_{E1} = 1.613\ \text{V}$$

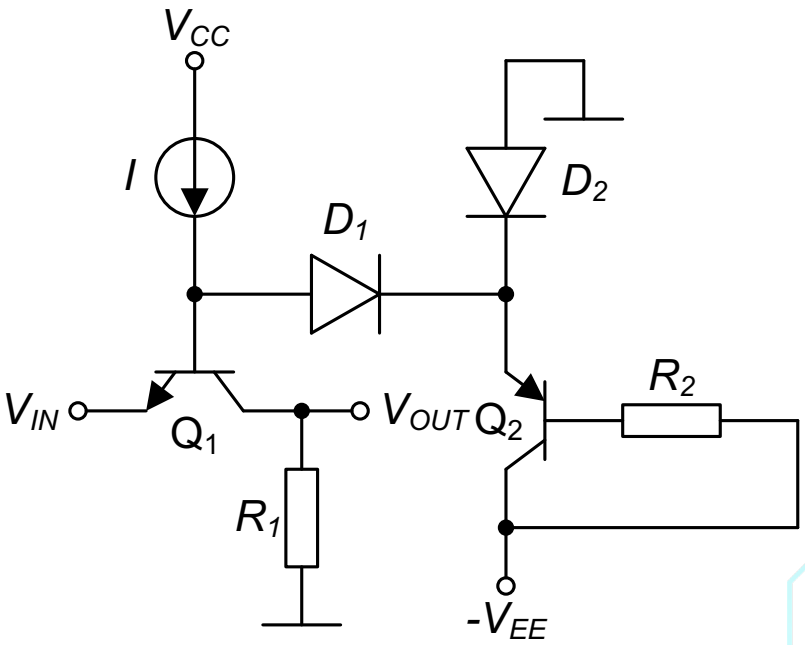
$$V_3 = -V_{EE} + R_3 I_3 = -1.853\ \text{V}$$

$$V_4 = -V_{EE} + R_5 I_{E2} = -2.552\ \text{V}$$

$$V_5 = V_{CC} - R_4 I_{C2} = 1.259\ \text{V}$$

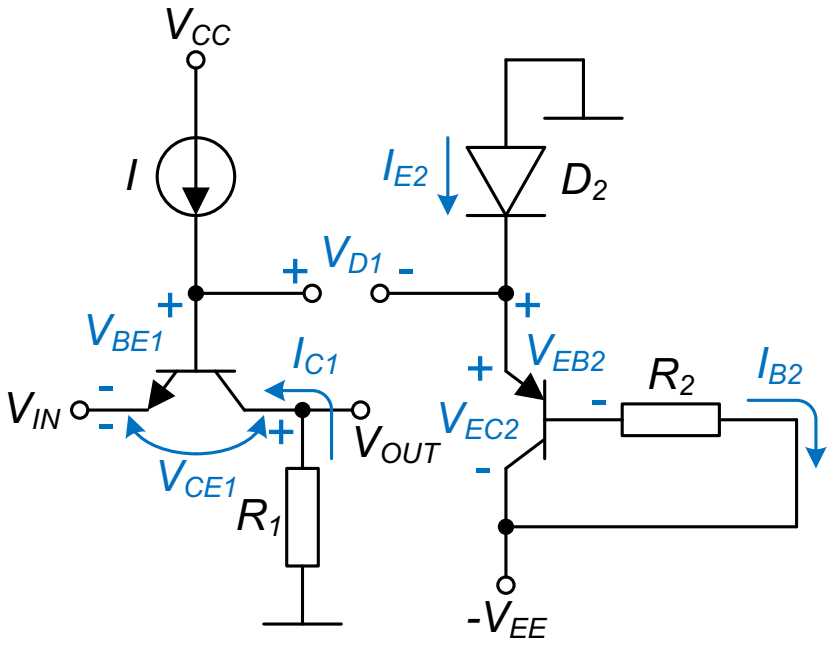
ZADATAK 2

Za kolo prikazano na slici 3 odrediti zavisnost izlaznog napona V_{OUT} od ulaznog napona V_{IN}, za opseg ulaznog napna – $V_{EE} < V_{IN} < V_{CC}$. Poznato je: $V_{CC}=V_{EE}=3.3$ V, $V_{D1}=V_{D2}=0.7$ V, $V_{BE1}=V_{EB2}=0.7$ V, $V_{CES1}=V_{ECS2}=0.2$ V, $\beta_1=\beta_2=\beta=100$, $R_1=2$ kΩ, $R_2=100$ kΩ, $I=10$ μA.



ZADATAK 2

1º Uvodi se pretpostavka da su oba BJT-a u DAR-u, dioda D_1 ne provodi, dok dioda D_2 provodi.



$$V_{OUT} = -R_1 I_{C1} = -R_1 \beta I = -2\ \text{V}$$

$$V_{CE1} = V_{OUT} - V_{IN} > V_{CES1}$$

$$V_{IN} < V_{OUT} - V_{CES1} = -2.2\ \text{V}$$

$$V_{D1} = V_{IN} + V_{BE1} + E_{D2} < E_{D1}$$

$$V_{IN} < E_{D1} - V_{BE1} - E_{D2} = -0.7\ \text{V}$$

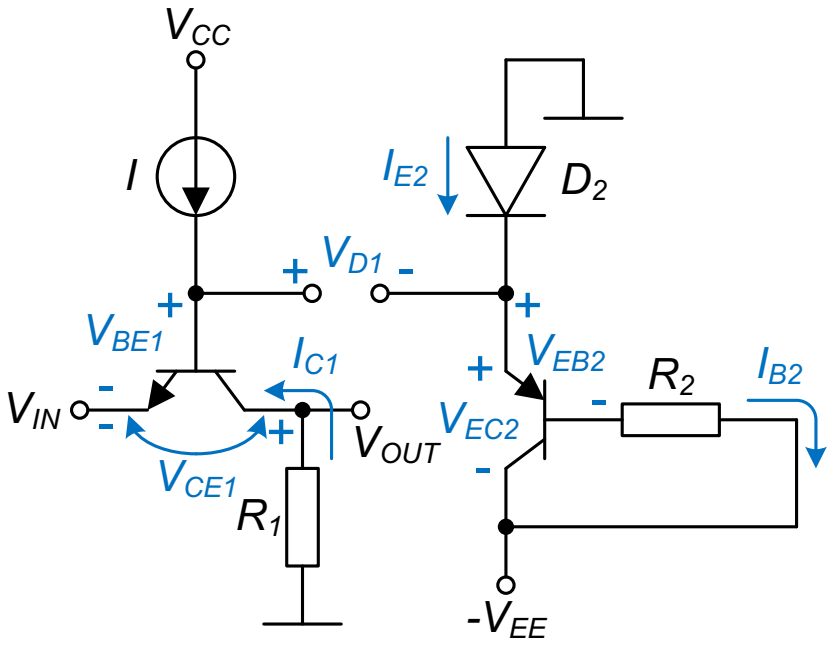
$$I_{B2} = \frac{-E_{D2} - V_{EB2} + V_{EE}}{R_2} = 19\ \mu\text{A}$$

$$I_{D2} = (\beta + 1) I_{B2} = 1.919\ \text{mA} > 0$$

$$V_{EC2} = -V_{D2} + V_{EE} = 2.6\ \text{V}$$

ZADATAK 2

2º Uvodi se pretpostavka da je BJT Q_1 u zasićenju, BJT Q_2 u DAR-u, dioda D_1 ne provodi, dok dioda D_2 provodi.



$$V_{OUT} = V_{IN} + V_{CES1}$$

$$I_{C1} = -\frac{V_{OUT}}{R_1} = -\frac{V_{IN} + V_{CES1}}{R_1} < \beta I$$

$$V_{IN} > -\beta I R_1 - V_{CES1} = -2.2\ \text{V}$$

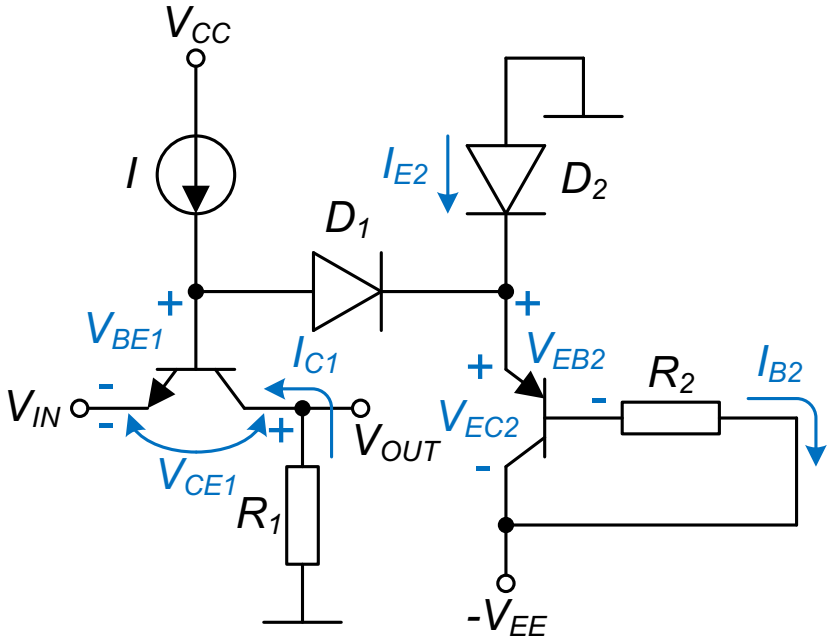
$$V_{D1} = V_{IN} + V_{BE1} + E_{D2} < E_{D1}$$

$$V_{IN} < E_{D1} - V_{BE1} - E_{D2} = -0.7\ \text{V}$$

$$-2.2\ \text{V} < V_{IN} < -0.7\ \text{V}$$

ZADATAK 2

3º Uvodi se pretpostavka da je BJT Q_1 u zasićenju, BJT Q_2 u DAR-u, i obje diode provode.



$$V_{OUT} = V_{IN} + V_{CES1}$$

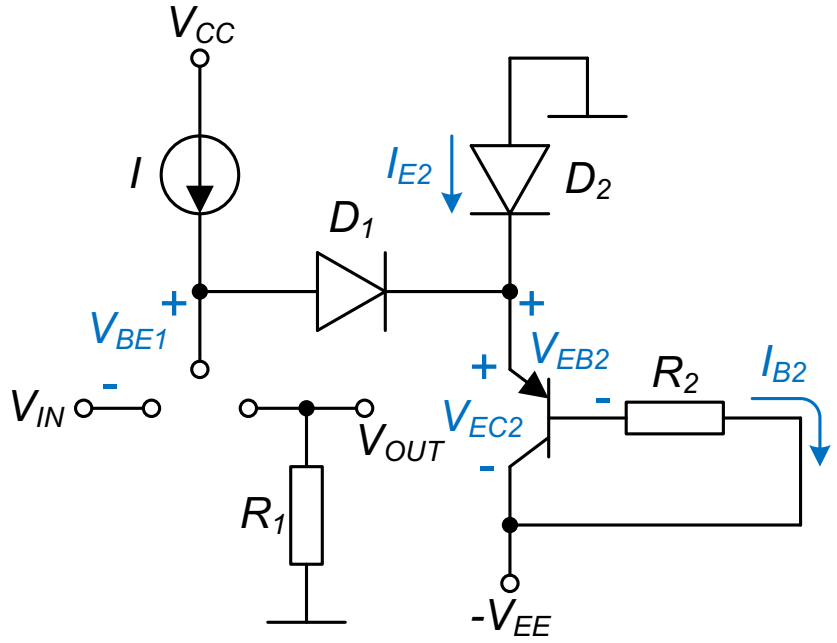
$$V_{IN} + V_{BE1} - E_{D1} + E_{D2} = 0$$

$$V_{IN} = -0.7\ \text{V}$$

$$V_{OUT} = -0.5\ \text{V}$$

ZADATAK 2

4º Uvodi se pretpostavka da je BJT Q_1 zakočen, BJT Q_2 u DAR-u, i obje diode provode.



$$V_{OUT} = 0\ \text{V}$$

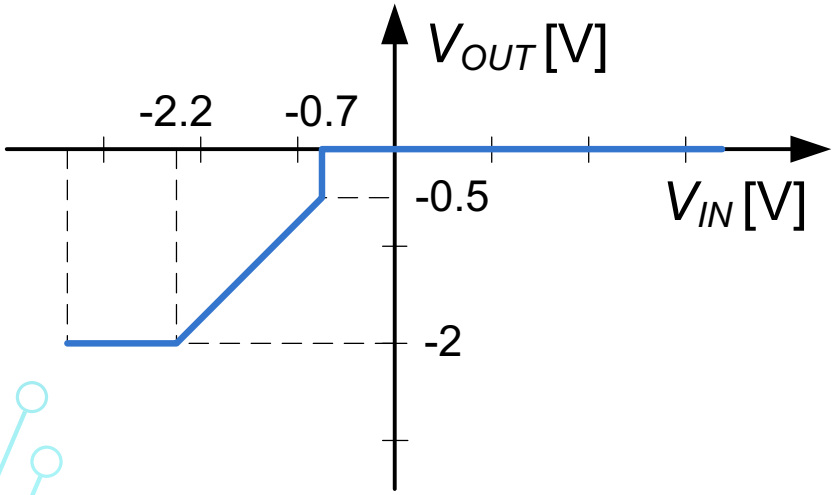
$$V_{BE1} = E_{D1} - E_{D2} - V_{IN} < 0.7\ \text{V}$$

$$V_{IN} > -0.7\ \text{V}$$

$$I_{D1} = I > 0$$

$$I_{D2} = (\beta + 1)I_{B2} - I_{D1} = 1.909\ \text{mA} > 0$$

ZADATAK 2



$V_{IN} < -2.2$ V: $V_{OUT} = -2$ V

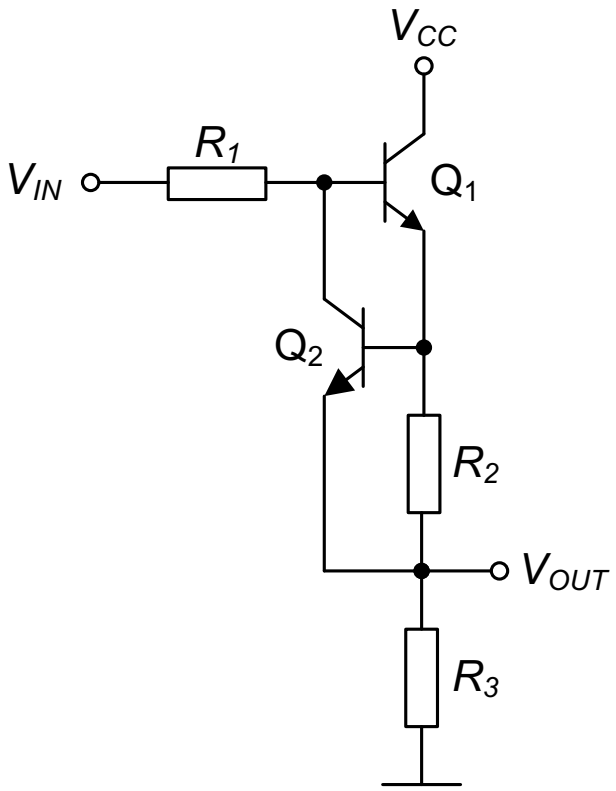
-2.2 V $< V_{IN} < -0.7$ V: $V_{OUT} = V_{IN} + V_{CES1}$

$V_{IN} = -0.7$ V: $V_{OUT} = -0.5$ V

$V_{IN} > -0.7$ V: $V_{OUT} = 0$ V

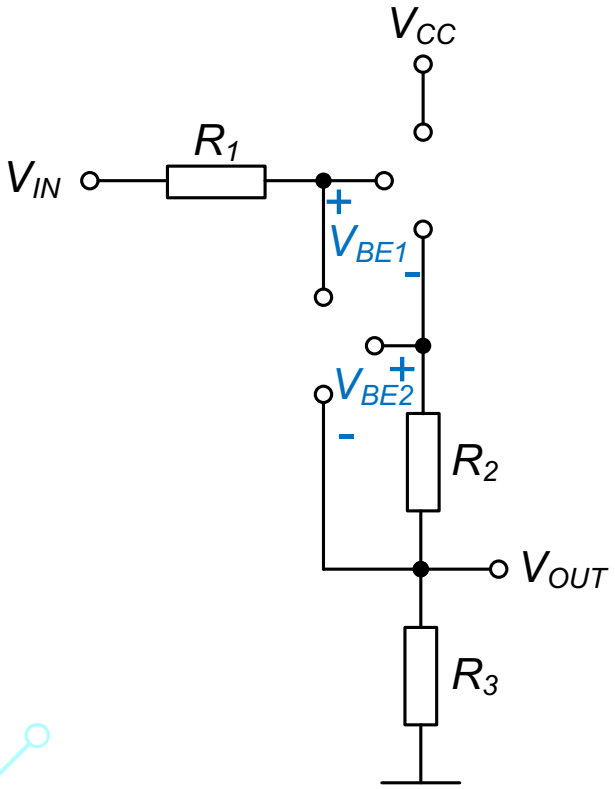
ZADATAK 2

Za kolo prikazano na slici odrediti zavisnost izlaznog napona V_{OUT} od ulaznog napona V_{IN}, za opseg ulaznog napna $0 < V_{IN} < V_{CC}$. Poznato je: V_{CC}=10 V, V_{BE1}=V_{BE2}=0.7 V, V_{CES1}=V_{CES2}=0.2 V, β_1=β_2=β=99, R_1=5 kΩ, R_2=200 Ω i R_3=1.6 kΩ.



ZADATAK 3

1º Uvodi se pretpostavka da su oba BJT-a zakočena.



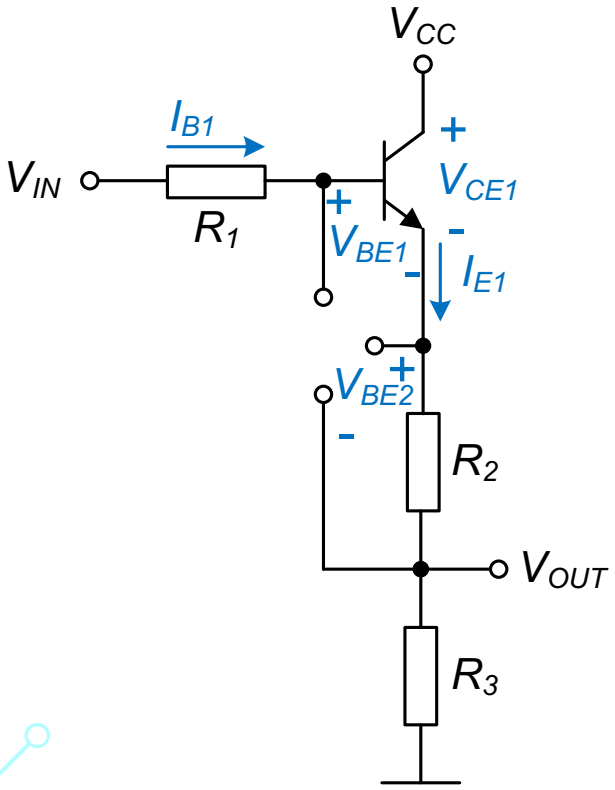
$$V_{OUT} = 0$$

$$V_{BE1} = V_{IN} < 0.7\ \text{V}$$

$$V_{BE2} = 0\ \text{V}$$

ZADATAK 3

2º Uvodi se pretpostavka da BJT Q_1 provodi u DAR-u, dok je Q_2 zakočen.



$$V_{IN} - R_1 I_{B1} - V_{BE1} - (R_2 + R_3) I_{E1} = 0$$

$$V_{IN} - R_1 I_{B1} - V_{BE1} - (R_2 + R_3)(\beta + 1) I_{B1} = 0$$

$$I_{B1} = \frac{V_{IN} - V_{BE1}}{R_1 + (R_2 + R_3)(\beta + 1)} > 0$$

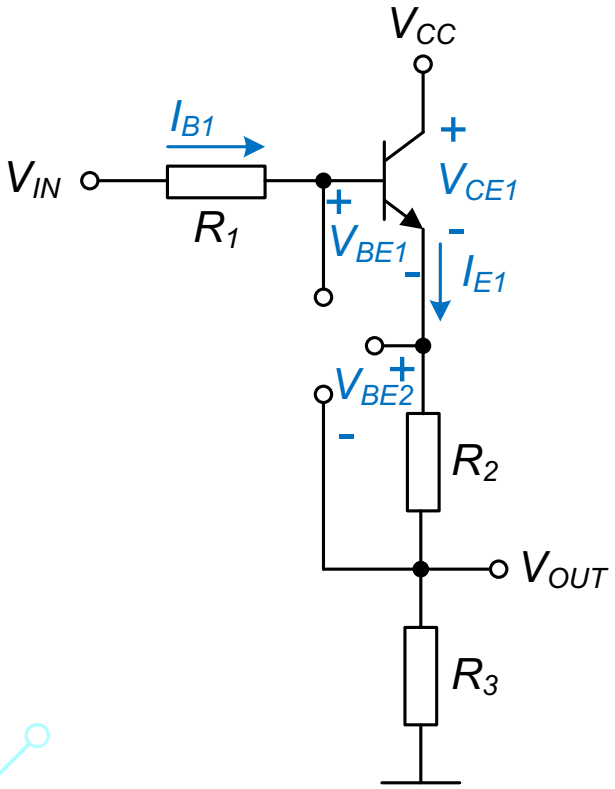
$$V_{IN} > V_{BE1}$$

$$V_{OUT} = R_3 I_{E1} = R_3(\beta + 1) \frac{V_{IN} - V_{BE1}}{R_1 + (R_2 + R_3)(\beta + 1)}$$

$$V_{OUT} = \frac{R_3(\beta + 1)}{R_1 + (R_2 + R_3)(\beta + 1)} (V_{IN} - V_{BE1})$$

ZADATAK 3

2º Uvodi se pretpostavka da BJT Q_1 provodi u DAR-u, dok je Q_2 zakočen.



$$V_{OUT} = 0.865(V_{IN} - V_{BE1})$$

$$V_{CE1} = V_{CC} - (R_2 + R_3)(\beta + 1)I_{B1}$$

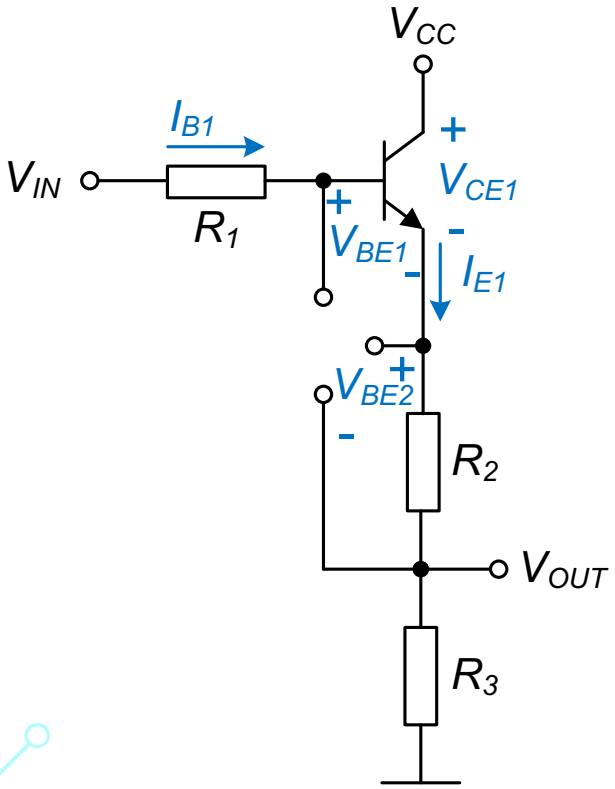
$$= V_{CC} - (R_2 + R_3)(\beta + 1)\frac{V_{IN} - V_{BE1}}{R_1 + (R_2 + R_3)(\beta + 1)} > V_{CES1}$$

$$\frac{V_{IN} - V_{BE1}}{R_1 + (R_2 + R_3)(\beta + 1)} < \frac{V_{CC} - V_{CES1}}{(R_2 + R_3)(\beta + 1)}$$

$$V_{IN} < \frac{R_1 + (R_2 + R_3)(\beta + 1)}{(R_2 + R_3)(\beta + 1)}(V_{CC} - V_{CES1}) + V_{BE1} = 10.77\ \text{V}$$

ZADATAK 3

2º Uvodi se pretpostavka da BJT Q_1 provodi u DAR-u, dok je Q_2 zakočen.



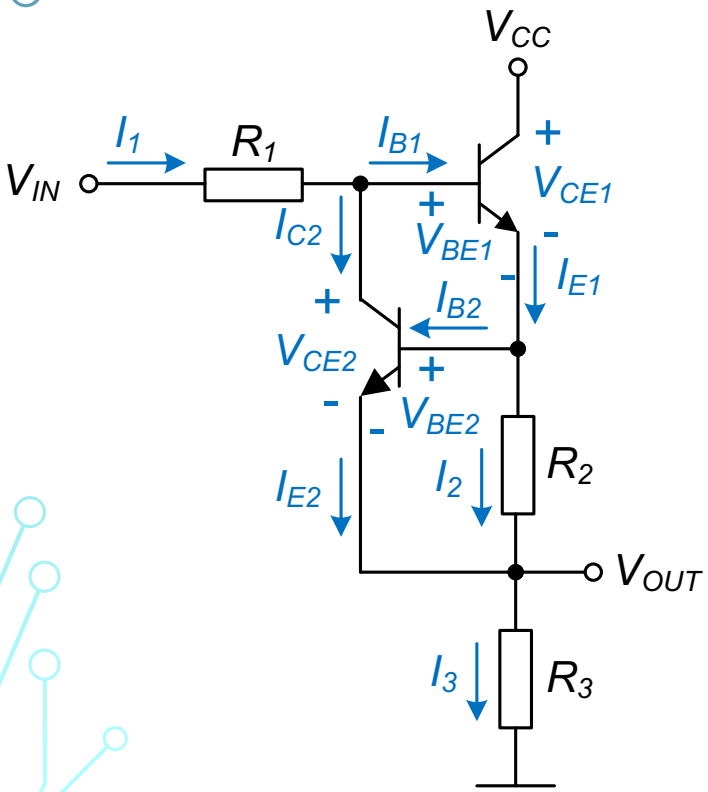
$$V_{BE2} = R_2(\beta+1)I_{B1} = R_2(\beta+1)\frac{V_{IN}-V_{BE1}}{R_1+(R_2+R_3)(\beta+1)} < 0.7\ \text{V}$$

$$V_{IN} < \frac{R_1+(R_2+R_3)(\beta+1)}{R_2(\beta+1)}0.7\ \text{V} + V_{BE1} = 7.175\ \text{V}$$

$$V_{OUT}(V_{IN} = 7.175\ \text{V}) = 5.6\ \text{V}$$

ZADATAK 3

3º Uvodi se pretpostavka da su oba BJT-a u DAR-u.



$$V_{OUT} = R_3 I_3$$

$$I_3 = I_{E2} + I_2$$

$$I_2 = \frac{V_{BE2}}{R_2} = 3.5\ \text{mA}$$

$$I_{E2} = (\beta + 1) I_{B2}$$

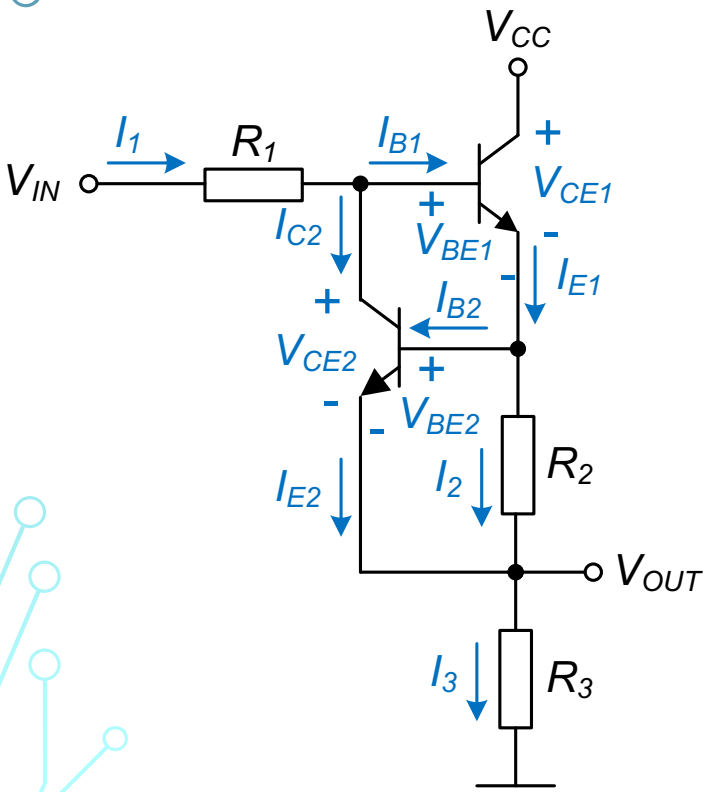
$$I_{B2} = I_{E1} - I_2$$

$$I_{E1} = (\beta + 1) I_{B1}$$

$$I_{B1} = I_1 - I_{C2} = I_1 - \beta I_{B2} = I_1 - \beta (I_{E1} - I_2)$$

ZADATAK 3

3º Uvodi se pretpostavka da su oba BJT-a u DAR-u.



$$I_{B1} = I_1 - I_{C2} = I_1 - \beta I_{B2} = I_1 - \beta(I_{E1} - I_2)$$

$$[1 + \beta(\beta + 1)]I_{B1} = I_1 + \beta I_2$$

$$I_{B1} = \frac{I_1 + \beta I_2}{1 + \beta(\beta + 1)}$$

$$I_1 = \frac{V_{IN} - V_{BE1} - V_{BE2} - V_{OUT}}{R_1}$$

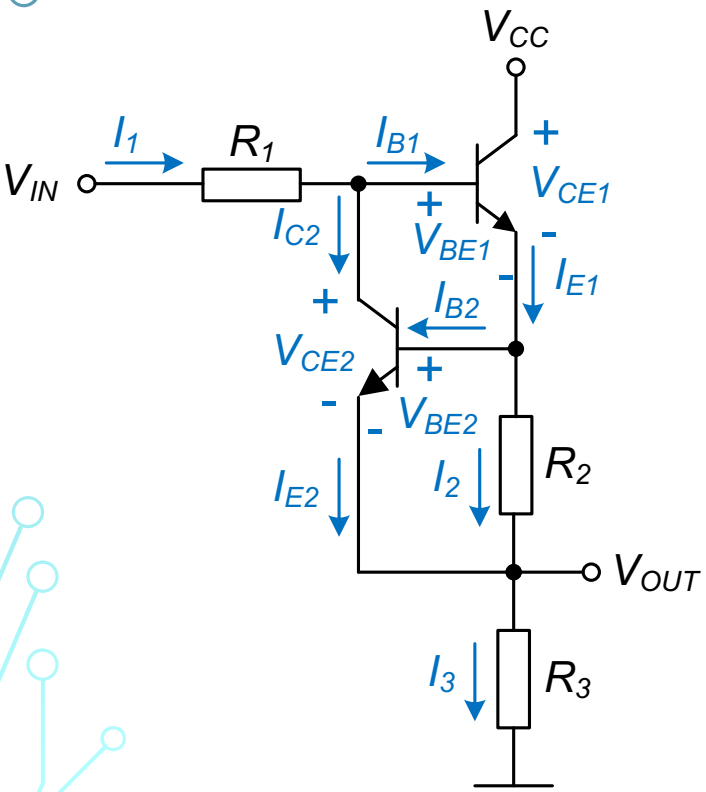
$$V_{OUT} = R_3(I_{E2} + I_2) = R_3[(\beta + 1)I_{B2} + I_2] = R_3[(\beta + 1)(I_{E1} - I_2) + I_2]$$

$$V_{OUT} = R_3\{(\beta + 1)[(\beta + 1)I_{B1} - I_2] + I_2\}$$

$$V_{OUT} = R_3\left\{(\beta + 1)\left[(\beta + 1)\frac{I_1 + \beta I_2}{1 + \beta(\beta + 1)} - I_2\right] + I_2\right\}$$

ZADATAK 3

3º Uvodi se pretpostavka da su oba BJT-a u DAR-u.



$$V_{OUT} = R_3\left\{(\beta+1)\left[(\beta+1)\frac{\frac{V_{IN}-V_{BE1}-V_{BE2}-V_{OUT}}{R_1}+\beta I_2}{1+\beta(\beta+1)}-I_2\right]+I_2\right\}$$

$$V_{OUT} = R_3\left[(\beta+1)^2\frac{\frac{V_{IN}-V_{BE1}-V_{BE2}-V_{OUT}}{R_1}+\beta I_2}{1+\beta(\beta+1)}-(\beta+1)I_2+I_2\right]$$

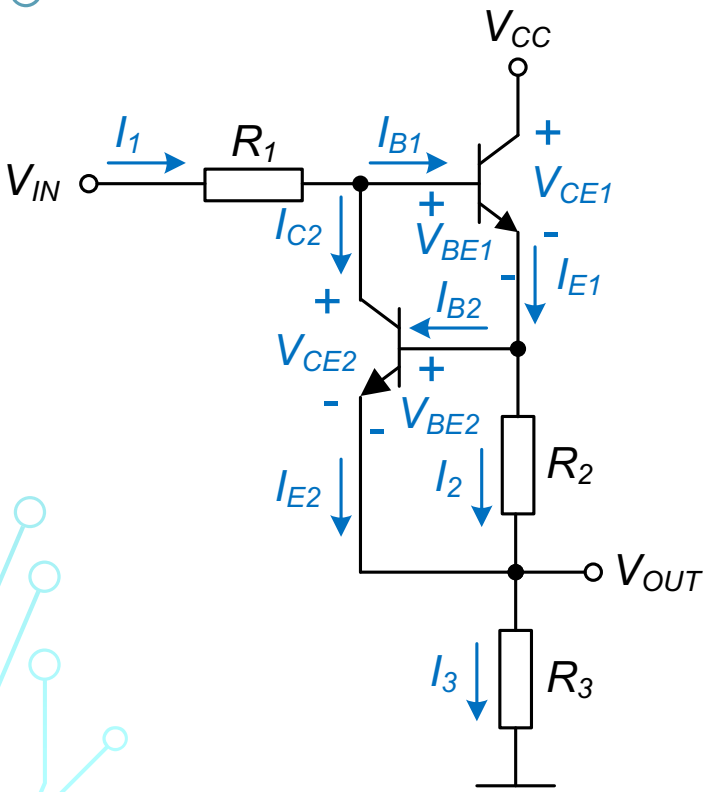
$$V_{OUT} = R_3\left[(\beta+1)^2\frac{V_{IN}-V_{BE1}-V_{BE2}-V_{OUT}+\beta R_1 I_2}{[1+\beta(\beta+1)]R_1}-(\beta+1)I_2+I_2\right]$$

$$\left[1+R_3\frac{(\beta+1)^2}{[1+\beta(\beta+1)]R_1}\right]V_{OUT}$$

$$= R_3\frac{(\beta+1)^2}{[1+\beta(\beta+1)]R_1}V_{IN}+R_3\left[(\beta+1)^2\frac{-V_{BE1}-V_{BE2}+\beta R_1 I_2}{[1+\beta(\beta+1)]R_1}-(\beta+1)I_2+I_2\right]$$

ZADATAK 3

3º Uvodi se pretpostavka da su oba BJT-a u DAR-u.



$$\left[1+\frac{R_3}{R_1}\right]V_{OUT} \approx \frac{R_3}{R_1}V_{IN} + R_3\left[\frac{-V_{BE1}-V_{BE2}}{R_1} + \frac{(\beta+1)^2\beta}{[1+\beta(\beta+1)]}I_2 - (\beta+1)I_2 + I_2\right]$$

$$V_{OUT} \approx \frac{R_3}{R_1+R_3}V_{IN} + \frac{R_3}{R_1+R_3}\left[-V_{BE1}-V_{BE2} + \frac{(\beta+1)^2\beta}{[1+\beta(\beta+1)]}R_1I_2 - \beta R_1 I_2\right]$$

$$V_{OUT} \approx \frac{R_3}{R_1+R_3}V_{IN} + \frac{R_3}{R_1+R_3}[-V_{BE1}-V_{BE2}+0.99R_1I_2]$$

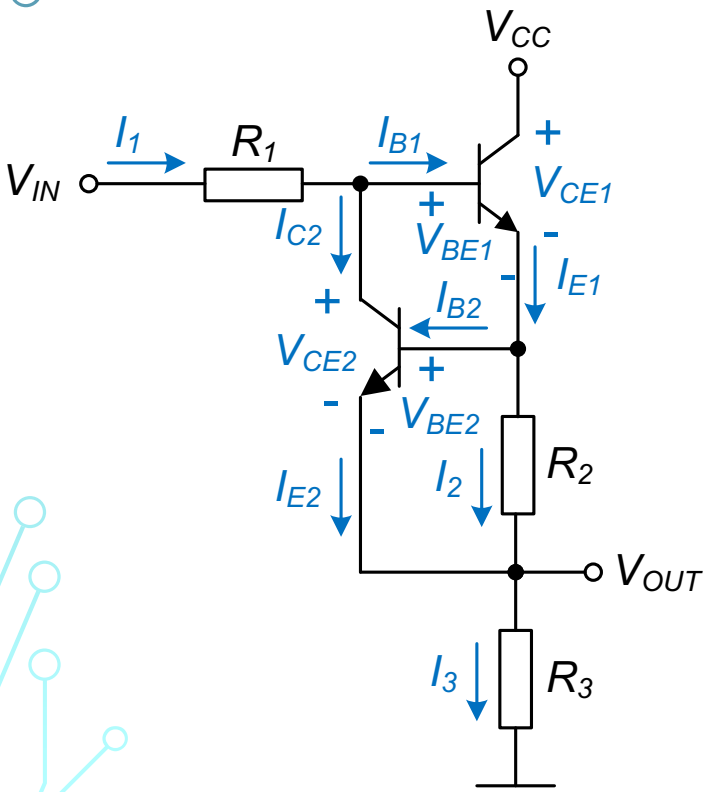
$$V_{OUT} \approx 0.242\,V_{IN} + 3.854\ \text{V}$$

$$V_{OUT}(V_{IN} = 7.175\ \text{V}) \approx 5.590\ \text{V}$$

$$V_{OUT}(V_{IN} = 10\ \text{V}) \approx 6.316\ \text{V}$$

ZADATAK 3

3º Uvodi se pretpostavka da su oba BJT-a u DAR-u.



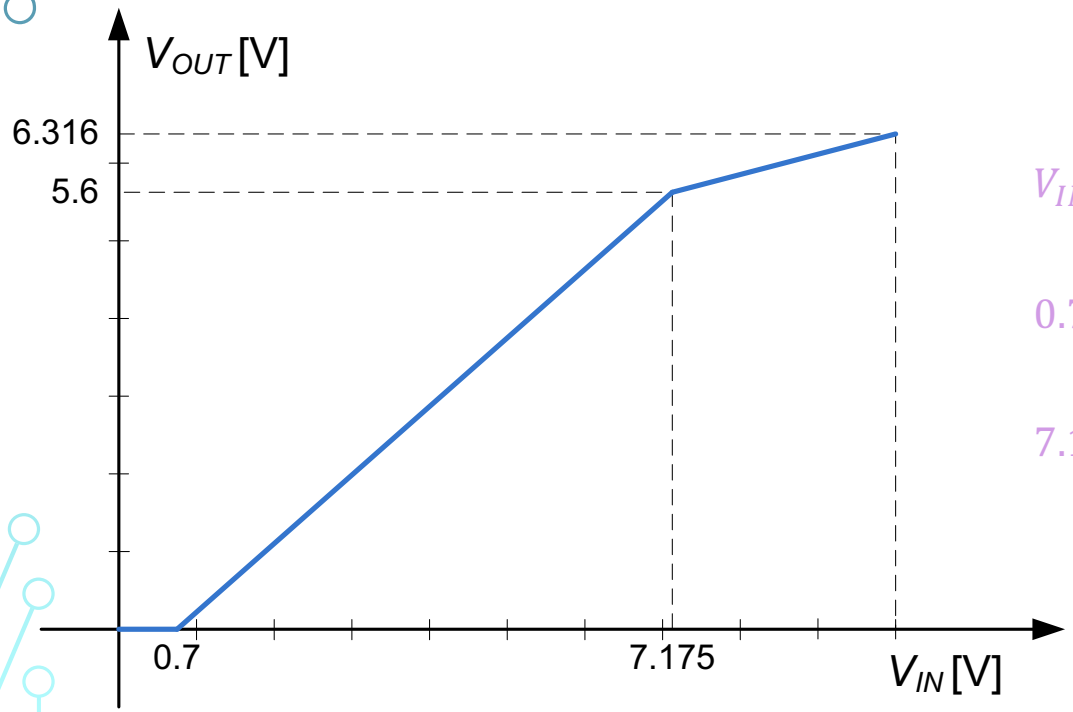
$$V_{CE1} = V_{CC} - V_{BE2} - V_{OUT} > V_{CES1}$$

$$10\ \text{V} - 0.7\ \text{V} - 0.242\ V_{IN} - 3.854\ \text{V} > 0.2\ \text{V}$$

$$V_{IN} < 21.68\ \text{V}$$

$$V_{CE2} = V_{BE1} + V_{BE2} = 1.4\ \text{V} > V_{CES2}$$

ZADATAK 3



$V_{IN} < 0.7$ V: $V_{OUT} = 0$

$0.7 \text{ V} < V_{IN} < 7.175$ V: $V_{OUT} = 0.865 V_{IN} - 0.605$ V

$7.175 \text{ V} < V_{IN} < 10$ V: $V_{OUT} \approx 0.242\, V_{IN} + 3.854$ V