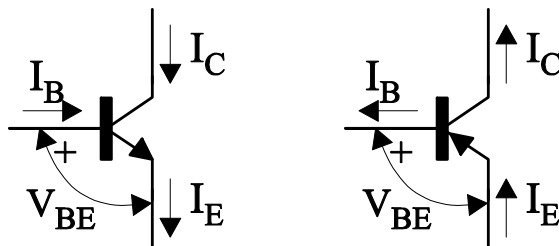


JEDNOSMERNI REŽIM U KOLIMA
SA BIPOLARNIM TRANZISTORIMA

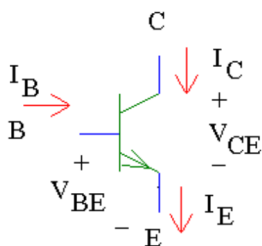


$$I_C = \beta \cdot I_B$$

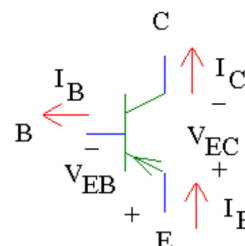
$$V_{BE} = V_B - V_E = \text{const}$$

$$I_E = I_B + I_C$$

n-p-n



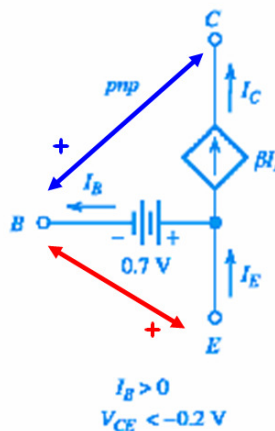
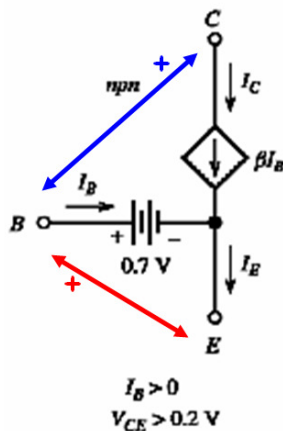
p-n-p



Large-Signal dc Analysis: Active-Region Model

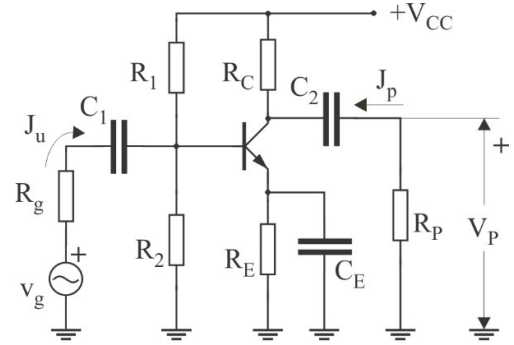
V_{BE} forward bias

V_{CB} reverse bias

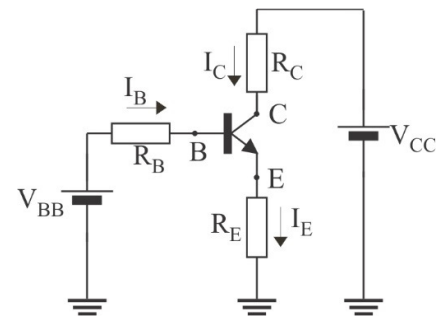
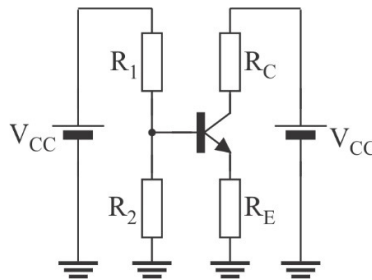
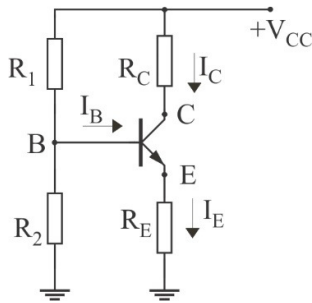


1) Za kolo pojačavača prikazano na slici odrediti jednosmernu struju kolektora i jednosmerni napon između kolektora i emitora.

Parametri tranzistori su: $\beta = 50$ i $V_{BE} = 0,7$ V. Elementi kola su $R_1 = 20$ k Ω , $R_2 = 2$ k Ω , $R_E = 500$ Ω , $R_C = 5$ k Ω i $V_{CC} = 12$ V.



Rešenje:



$$V_{BB} = \frac{V_{CC} \cdot R_2}{R_1 + R_2} = 1,09 \text{ V}$$

$$R_B = \frac{R_1 \cdot R_2}{R_1 + R_2} = 1,81 \text{ k}\Omega$$

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

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

$$I_B = \frac{V_{BB} - V_{BE}}{R_B + (1 + \beta) \cdot R_E} = 14 \mu\text{A}$$

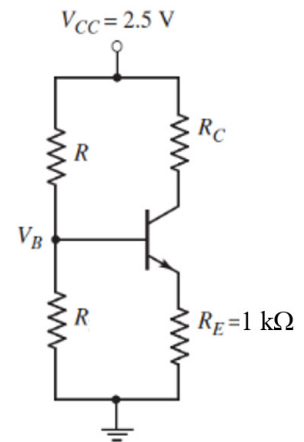
$$I_C = \beta \cdot I_B = 0,7 \text{ mA}$$

$$V_C = V_{CC} - R_C \cdot I_C = 8,5 \text{ V}$$

$$V_E = R_E \cdot I_E = 0,36 \text{ V}$$

$$V_{CE} = V_C - V_E = 8,14 \text{ V}$$

2) Tranzistor u kolu sa slike ima koeficijent strujnog pojačanja $\beta = 120$. Odrediti nepoznate elemente u kolu tako da jednosmerna struja kolektora iznosi $I_C = 0,2 \text{ mA}$ a jednosmeran napon između kolektora i emitora $V_{CE} = 1,5 \text{ V}$. Smatrati $\beta \gg 1$, $V_{BE} = 0,7 \text{ V}$.



Rešenje:

$$V_{BB} = V_{CC} \cdot \frac{R}{R+R} = V_{CC} \cdot \frac{1}{2} = 1,25 \text{ V}$$

$$R_B = \frac{R \cdot R}{R+R} = \frac{R}{2}$$

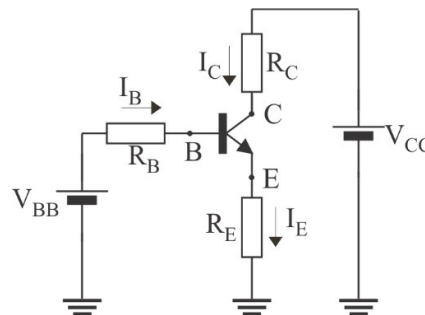
$$-V_{BB} + R_B \cdot I_B + V_{BE} + R_E \cdot I_E = 0$$

$$I_E = (1 + \beta) \cdot I_B \approx \beta \cdot I_B$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B + \beta \cdot R_E} = \frac{I_C}{\beta}$$

$$R_B = \beta \cdot \left(\frac{V_{BB} - V_{BE}}{I_C} - R_E \right) = 270 \text{ k}\Omega$$

$$R = 2 R_B = 540 \text{ k}\Omega$$

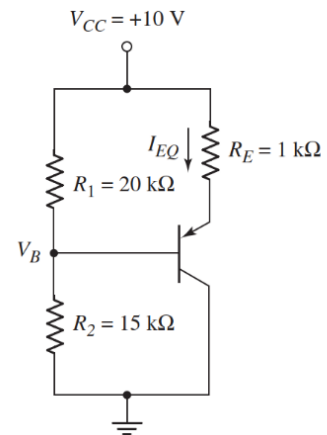


$$V_C = V_{CE} + V_E = V_{CE} + R_E \cdot I_E = V_{CE} + R_E \cdot I_C = 1,7 \text{ V}$$

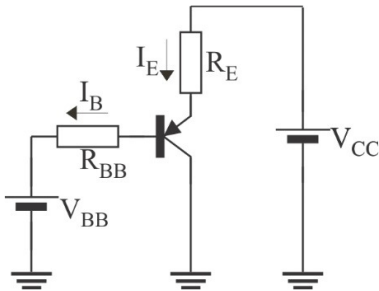
$$V_C = V_{CC} - R_C \cdot I_C$$

$$R_C = \frac{V_{CC} - V_C}{I_C} = 4 \text{ k}\Omega$$

3) Odrediti jednosmernu struju kolektora I_C i jednosmerni napon između kolektora i emitora tranzistora u kolu sa slike. Parametri tranzistor su $\beta = 100$, $V_{BE} = -0,7 V$.



Rešenje:



$$V_{BB} = V_{CC} \cdot \frac{R_2}{R_2 + R_1} = 10 \cdot \frac{15}{35} = 4,28 V$$

$$R_{BB} = \frac{R_1 \cdot R_2}{R_1 + R_2} = 8,57 k$$

$$-V_{BB} - R_B \cdot I_B + V_{BE} - R_E \cdot I_E + V_{CC} = 0$$

$$I_B = \frac{V_{CC} + V_{BE} - V_{BB}}{R_B + (\beta + 1) \cdot R_E} = \frac{10V - 0,7V - 4,28V}{8,57 k\Omega + 101 k\Omega} = 45,8 \mu A$$

$$I_E = \beta \cdot I_B = 4,58 mA$$

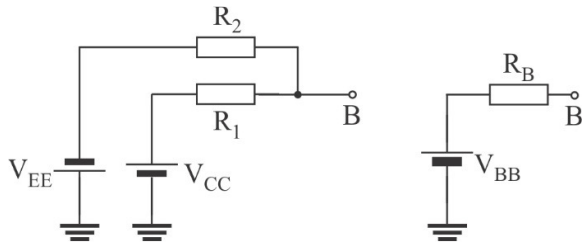
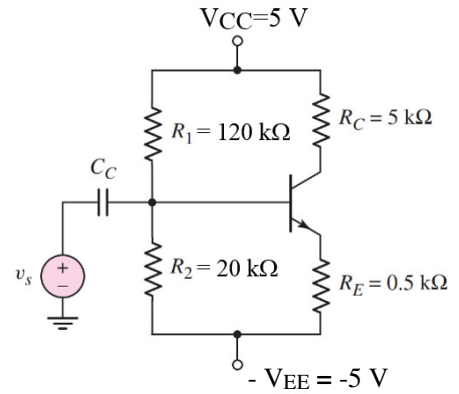
$$V_E = V_{CC} - R_E \cdot I_E = V_{CC} - R_E(1 + \beta) \cdot I_B = 10V - 0,046 \cdot 101V = 5,37 V$$

$$V_{CE} = V_C - V_E = -V_E = -5,37 V$$

4. Zadatak

Odrediti radnu tačku tranzistora u kolu sa slike (V_{CE} , I_C).
 Parametri tranzistor su $\beta = 100$, $V_{BE} = 0,7 V$. Smatrati da je $\beta \gg 1$.

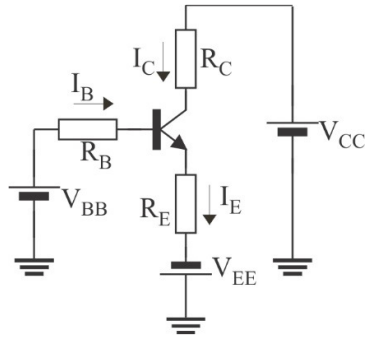
Rešenje:



$$V_{BB} = V_{CC} \cdot \frac{R_2}{R_1 + R_2} - V_{EE} \cdot \frac{R_1}{R_1 + R_2} = 5 \cdot \frac{1}{7} V - 5 \cdot \frac{6}{7} V = -3,57 V$$

$$R_{BB} = \frac{R_1 \cdot R_2}{R_1 + R_2} = 17 k\Omega$$

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



$$I_B = \frac{V_{BB} - V_{BE} + V_{EE}}{R_B + \beta \cdot R_E} = \frac{0,73}{67 k\Omega} = 10,9 \mu A$$

$$I_C = I_B \cdot \beta = 1,1 mA$$

$$V_E = -V_{EE} + R_E \cdot I_E = -V_{EE} + R_E (1 + \beta) \cdot I_B = -4,45 V$$

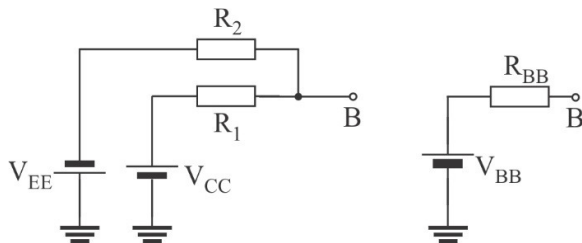
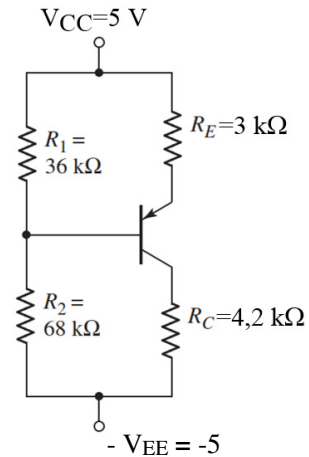
$$V_C = V_{CC} - R_C \cdot I_C = V_{CC} - R_C \cdot \beta \cdot I_B = -0,04 V$$

$$V_{CE} = V_C - V_E = 4,41 V$$

5. Zadatak

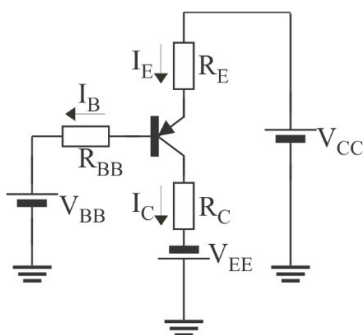
Odrediti radnu tačku tranzistora sa slike. Tranzistor u kolu sa slike ima koeficijent strujnog pojačanja $\beta = 80$ i napon između baze i emitora $V_{BE} = -0,7V$.

Rešenje:



$$V_{BB} = V_{CC} \cdot \frac{R_2}{R_1 + R_2} - V_{EE} \cdot \frac{R_1}{R_1 + R_2} = 5 \cdot 0,65 V - 5 \cdot 0,34 V = 1,55 V$$

$$R_{BB} = \frac{R_1 \cdot R_2}{R_1 + R_2} = 23,53 k\Omega$$



$$-V_{BB} - R_B \cdot I_B + V_{BE} - R_E \cdot I_E + V_{CC} = 0$$

$$I_B = \frac{V_{CC} + V_{BE} - V_{BB}}{R_B + (\beta + 1) \cdot R_E} = \frac{5 - 0,7 - 1,55}{23,53 + 81 \cdot 3} = 10,47 \mu A$$

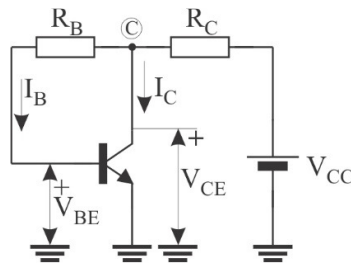
$$I_C = \beta \cdot I_B = 0,8 mA$$

$$V_E = V_{CC} - R_E \cdot I_E = V_{EE} - R_E(1 + \beta) \cdot I_B = 2,46 V$$

$$V_C = -V_{EE} + R_C \cdot I_C = -V_{EE} + R_C \cdot \beta \cdot I_B = -1,48 V$$

$$V_{CE} = V_C - V_E = -3,94 V$$

6) U kolu sa slike upotrebljen je silicijumski tranzistor sa $\beta = 50$, $I_{C0} = 0$ A i $V_{BE} = 0,7$ V. Poznato je: $V_{CC} = 10$ V; $R_C = 2$ k Ω ; $R_B = 100$ k Ω . Odrediti radnu tačku tranzistora: I_B , I_C i V_{CE} .



Jednačine modela

$$V_B = V_{BE}$$

$$I_C = I_B \cdot \beta$$

Jednačine po metodu potencijala čvorova

$$\frac{V_B - V_C}{R_B} + I_B = 0$$

$$\frac{V_C - V_{CC}}{R_C} + \frac{V_C - V_B}{R_B} + I_C = 0$$

$$V_C = V_B + R_B \cdot I_B = V_{BE} + R_B \cdot I_B$$

Nakon sabiranja jednačine za čvor baze i čvor kolektora dobija se:

$$\frac{V_C - V_{CC}}{R_C} + I_B + I_C = 0$$

$$V_{BE} + R_B \cdot I_B - V_{CC} + R_C \cdot I_B + R_C \cdot I_C = 0$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (1 + \beta) \cdot R_C} = 46 \mu A$$

$$I_C = \beta \cdot I_B = 2,3 \text{ mA}$$

Iz jednačine čvora baze

$$V_{CE} = V_C = R_B \cdot I_B + V_{BE} = 5,31 \text{ V}$$

II Način rešavanja, direktna primena Kirchofovih zakona

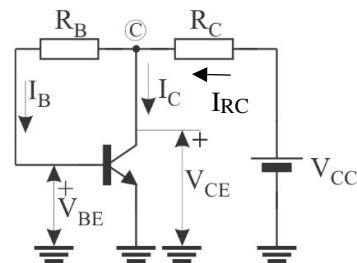
Jednačina konture koja obuhvata emitorski pn spoj, VBE:

$$V_{CC} = V_{BE} + R_B \cdot I_B + R_C \cdot I_{RC}$$

Jednačina čvora kolektora

$$I_{RC} = I_C + I_B = (1 + \beta) \cdot I_B$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (1 + \beta) \cdot R_C} = 46 \mu A$$



Jednačina po Kirhofovom zakonu za napone može da se kreira za konturu koja obuhvata emitorski pn spoj, V_{BE} . Bila bi greška napisati konturu koja obuhvata neke druge napone tranzistora, V_{CE} ili V_{CB} , jer ovi naponi nisu unapred poznati.