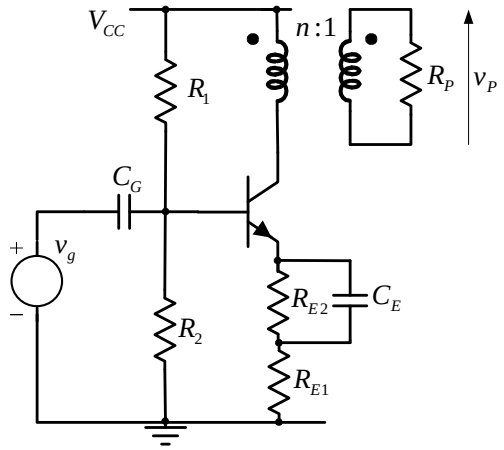
2. Na slici 2 je prikazan pojačavač snage u klasi A. Poznato je: $R_1 = 111\,\Omega$, $R_2 = 39\,\Omega$, $R_{E1} = 1\,\Omega$, $R_{E2} = 7\,\Omega$, $R_P = 4\,\Omega$, $V_{CC} = 15\,\text{V}$, $\beta_F = 50$, $V_{BE} = 0.7\,\text{V}$, $V_{CES} = 0.5\,\text{V}$, $L_m \to \infty$, $C_G \to \infty$, $C_E \to \infty$, $n = 2$. Napon na izlazu je sinusnog talasnog oblika maksimalne moguće amplitude za zadate parametre.

a) [3] Nacrtati jednosmernu i dinamičku radnu pravu pojačavača.

b) [10] Odrediti i nacrtati vremenske oblike napona v_P i v_{CE}, struja i_P i i_C, i snaga p_P, p_D i p_{CC}.

c) [3] Izračunati koeficijent korisnog dejstva pojačavača.

d) [4] Izvesti izraz za optimalnu vrednost parametra n, tako da se na izlazu dobija najveća moguća amplituda neizobličenog napona.



Slika 2

Rešenje:

a)

Jednosmerna radna prava:

$$V_{CEQ} = V_{CC} - (R_{E1} + R_{E2})\frac{\beta + 1}{\beta} I_{CQ} = 15 - 8.16 I_{CQ}$$

Određivanje I_{CQ} i V_{CEQ}:

$$\frac{V_{CC} - V_B}{R_1} = \frac{V_B}{R_2} + I_B$$

$$I_E = \frac{V_B - V_{BE}}{R_{E1} + R_{E2}} = (1 + \beta_F) I_B$$

$$V_B = \frac{\dfrac{V_{BE}}{R_{E1} + R_{E2}} + \dfrac{(1 + \beta_F) V_{CC}}{R_1}}{\dfrac{1}{R_{E1} + R_{E2}} + \dfrac{1 + \beta_F}{R_1 \parallel R_2}} = 3.7\ \text{V}$$

$$V_E = V_B - V_{BE} = 3\text{V}$$

$$I_E = \frac{V_E}{R_E} = 375\text{mA}$$

$$I_{CQ} = \frac{\beta_F}{\beta_F + 1} I_E = 368\text{mA}$$

$$V_{CEQ} = V_{CC} - R_E I_{EQ} = 12\text{V}$$

Dinamička radna prava:

$$i_c = -\frac{v_{ce}}{n^2 R_P + R_{E1}}$$

$$i_C - I_{CQ} = -\frac{v_{CE} - V_{CEQ}}{n^2 R_P + R_{E1}}$$

$$i_C = I_{CQ} + \frac{V_{CEQ}}{n^2 R_P + R_{E1}} - \frac{v_{CE}}{n^2 R_P + R_{E1}} = 1.074 - \frac{v_{CE}}{17}$$

Uslov da se tranzistor ne isključi:

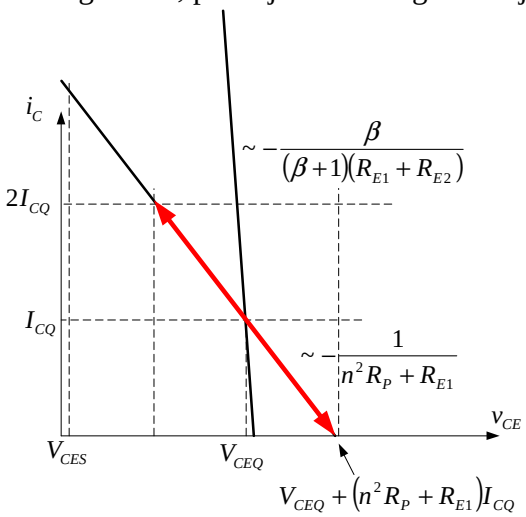
$$i_C > 0$$

$$I_{CQ} - \frac{v_{CE} - V_{CEQ}}{n^2 R_P + R_{E1}} > 0$$

$$v_{CE} < \left(n^2 R_P + R_{E1}\right) I_{CQ} + V_{CEQ},\ v_{CE\max} = 18.256\text{ V}$$

$$V_{ce\max} = 6.256\text{ V} \left(< V_{CEQ} - V_{CES}\right) \text{ - ograničenje}$$

Nema potrebe proveravati drugi uslov, pošto je uočeno ograničenje, i to usled isključenja.



$$V_p = \frac{1}{n} V_c = \frac{1}{n} \frac{n^2 R_P}{n^2 R_P + R_{E1}} V_{ce\max} = 2.944\text{ V}$$

b)

$$v_p = V_p \sin \omega t = 2.944\text{ V} \sin \omega t$$

$$v_{CE} = V_{CEQ} + v_{CE} = V_{CEQ} - \frac{n^2 R_P + R_{E1}}{n^2 R_P} v_C = V_{CEQ} - \frac{n^2 R_P + R_{E1}}{n^2 R_P} n v_P =$$

$$= V_{CEQ} - \frac{n^2 R_P + R_{E1}}{n^2 R_P} n V_p \sin \omega t = 12\text{ V} - 6.256\text{ V} \sin \omega t$$

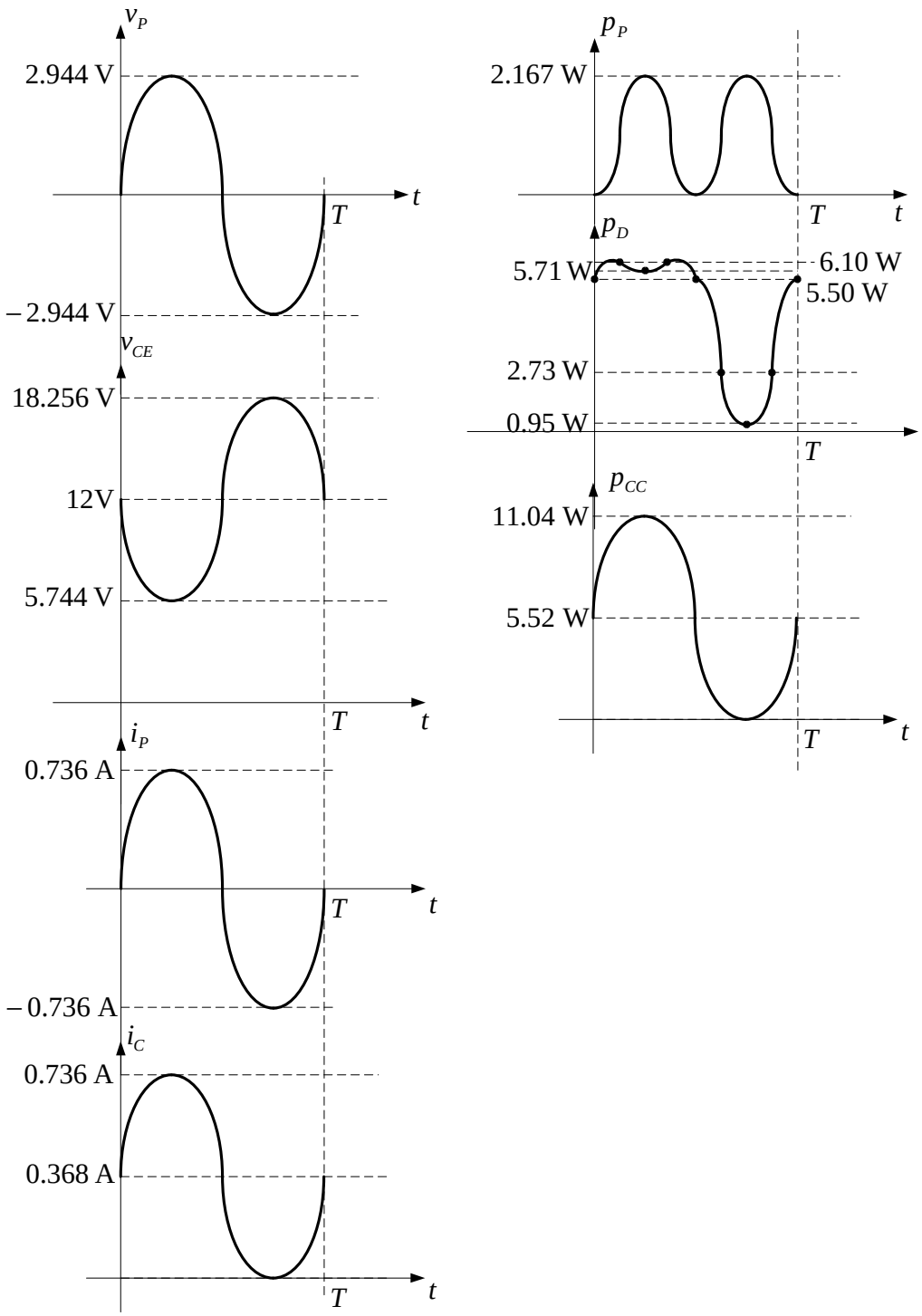
$$i_p = \frac{v_P}{R_P} = \frac{V_p}{R_P}\sin\omega t = 0.736\ \text{A}\sin\omega t$$

$$i_C = I_{CQ} + \frac{i_P}{n} = I_{CQ} + \frac{1}{n}\frac{V_p}{R_P}\sin\omega t = 0.368\ \text{A}(1+\sin\omega t)$$

$$p_P = \frac{{v_P}^2}{R_P} = \frac{{V_p}^2}{R_P}\sin^2\omega t = 2.167\ \text{W}\sin^2\omega t$$

$$p_D = v_{CE}i_C + R_{E1}{i_C}^2 + R_{E2}{I_{CQ}}^2 = (v_{CE} + R_{E1}i_C)i_C + R_{E2}{I_{CQ}}^2 =$$
$$= [(12\ \text{V} - 6.256\ \text{V}\sin\omega t) + (0.368\ \text{V}(1+\sin\omega t))]0.368\ \text{A}(1+\sin\omega t) + 0.948\ \text{W} =$$
$$= 0.368(12.368 - 5.888\sin\omega t)(1+\sin\omega t)\ \text{W} + 0.948\ \text{W} = (5.50 + 2.38\sin\omega t - 2.17\sin^2\omega t)\ \text{W}$$

$$p_D(0) = 5.50\ \text{W},\ p_D\left(\frac{T}{8}\right) = 6.10\ \text{W}$$
$$p_D\left(\frac{T}{4}\right) = 5.71\ \text{W},\ p_D\left(\frac{3T}{8}\right) = 6.10\ \text{W}$$
$$p_D\left(\frac{T}{2}\right) = 5.50\ \text{W},\ p_D\left(\frac{5T}{8}\right) = 2.73\ \text{W}$$
$$p_D\left(\frac{3T}{4}\right) = 0.95\ \text{W},\ p_D\left(\frac{7T}{8}\right) = 2.73\ \text{W}$$
$$p_{CC} = V_{CC}i_C = 5.52\ \text{W}(1+\sin\omega t)$$


v_P
2.944 V
t
T
– 2.944 V
v_{CE}
18.256 V
12V
5.744 V
T
t
i_P
0.736 A
T
t
– 0.736 A
i_C
0.736 A
0.368 A
T
t
p_P
2.167 W
T
t
p_D
5.71 W
6.10 W
5.50 W
2.73 W
0.95 W
T
p_{CC}
11.04 W
5.52 W
T
t

c)

$$P_P = \overline{p_P} = \frac{V_p^{\,2}}{R_P}\overline{\sin^2 \omega t} = \frac{V_p^{\,2}}{2R_P} = 1.0835 \text{ W}$$

$$P_{CC} = \overline{p_{CC}} = V_{CC}\overline{i_C} = 5.52 \text{ W}$$

$$\eta = \frac{P_P}{P_{CC}} = 19.63\%$$

d)

Maksimalna amplituda neizobličenog napona dobija se kada se mirna radna tačka nalazi na polovini dinamičke radne prave, odnosno ako se istovremeno dostižu naponsko i strujno ograničenje:

$$i_{C\max} = 2I_{CQ} = I_{CQ} + \frac{V_{CEQ} - V_{CES}}{n^2 R_P + R_{E1}}$$

$$v_{CE\min} = V_{CES} = V_{CEQ} - \left(n^2 R_P + R_{E1}\right) I_{CQ}$$

$$n_{OPT} = \sqrt{\frac{\frac{V_{CC} - V_{CES}}{I_{CQ}} - R_{E1}\left(1 + \frac{\beta + 1}{\beta}\right) - R_{E2}\frac{\beta + 1}{\beta}}{R_P}} = 2.75$$