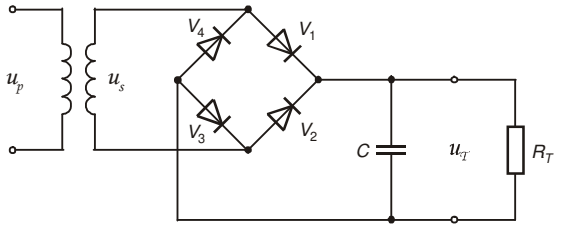
04.02.2000., Zagreb

Pismeni ispit iz Analognih sklopova

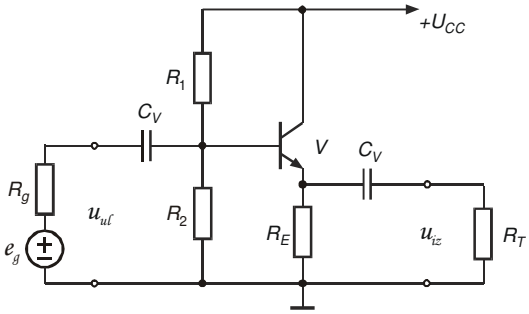
Svaki zadatak nosi po 10 bodova. Za prolaz je potrebno 25 bodova od čega bar jedan cijeli točan zadatak.

1. Za ispravljač na slici odredite vrijednost kapaciteta C, tako da se na trošilu otpora R = 100 Ω dobiva srednja vrijednost napona U_{sr} = 12 V uz napon valovitosti U_{vpp} = 100 mV. Izračunati i omjer $n = U_{pm}/U_{sm}$, faktor valovitosti r te snagu na trošilu P. U_p = 220V, f = 50 Hz.
2. Za pojačalo na slici izračunajte statičku radnu točku, ulazni i izlazni otpor te strujno i naponsko pojačanje. Poznato je: U_{CC} = 12 V, R_1 = 330 kΩ, R_2 = 560 kΩ, R_E = 3,9 kΩ, R_T = 50 Ω, R_g = 8,2 kΩ, β = h_{fe} = 120.
3. Za pojačalo na slici izračunajte statičku radnu točku, ulazni i izlazni otpor te naponsko pojačanje. Poznato je: U_{DD} = 15 V, R_1 = 5,6 MΩ, R_2 = 680 kΩ, R_S = 470 Ω, R_D = 1,5 kΩ, R_T = 47 kΩ, R_g = 100 kΩ, U_{GS0} = −3 V, K = 1,5 mA/V^2, μ = 80.
4. Za pojačalo na slici potrebno je odrediti statičke radne točke tranzistora te izlazne napone na oba izlaza i njihovu razliku, ako su ulazni naponi u_{ul1} = 2mV, u_{ul2} = 0 V. Poznato je: U_{CC} = 9 V, U_{EE} = 9 V, R_C = 1,8 kΩ, R_B = 470 kΩ, R_E = 470 Ω, β= 120, U_{BEQ} = 0,7 V.
5. Izračunajte i nacrtajte amplitudnu i faznu frekvencijsku karakteristiku zadanog sklopa. Poznato je: C_1 = 4,7 nF, C_2 = 100 nF, R_1 = 4,7 kΩ, R_2 = 100 kΩ.

1.



2.



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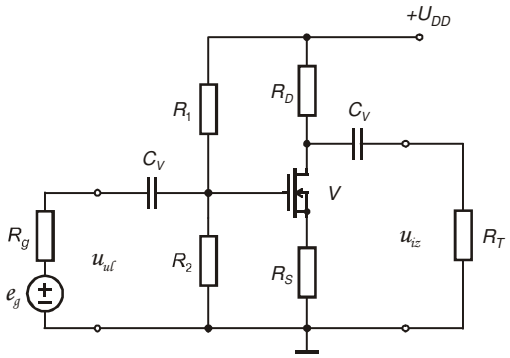

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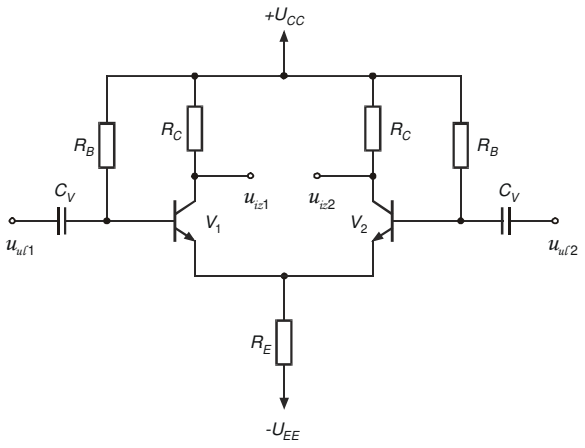

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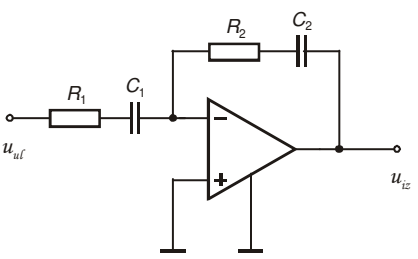
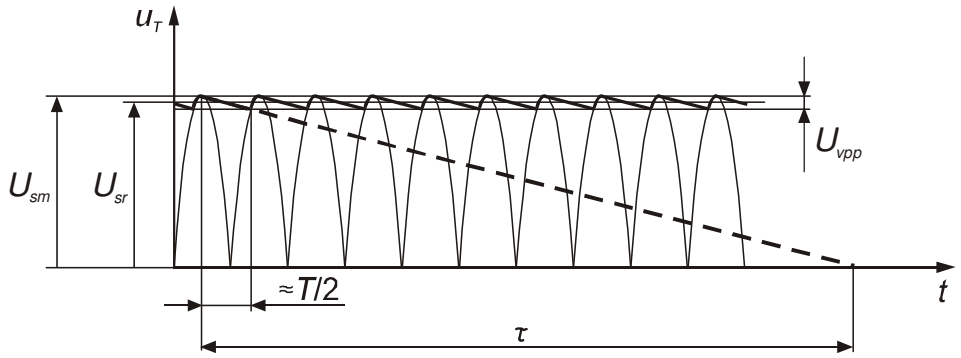


1.



Izmjenična komponenta napona na trošilu može se nadomjestiti pilastim naponom, ako je vremenska konstanta τ mnogo veća od trajanja poluperiode ulaznog napona. Time je analiza znatno olakšana, a pogreške zbog navedene aproksimacije su zadovoljavajuće male.

2 boda

$$U_{sm} = U_{sr} + \frac{U_{vpp}}{2} = 12{,}05V$$

3 boda

$$\frac{U_{sm}}{\tau} = \frac{U_{vpp}}{T/2} \qquad \tau = \frac{U_{sm} \cdot T}{2 \cdot U_{vpp}} = RC$$

$$C = \frac{U_{sm} \cdot T}{2U_{vpp} \cdot R} = \frac{12{,}05 \cdot 0{,}02}{2 \cdot 0{,}1 \cdot 100} = 12{,}05mF$$

5 bodova

$$n = \frac{U_{pm}}{U_{sm}} = \frac{220\sqrt{2}}{12{,}05} = 25{,}8$$

6 bodova

$$r = \frac{U_v}{U_{sr}} = \frac{U_{vpp}}{2\sqrt{3} \cdot U_{sr}} = 2{,}41 \cdot 10^{-3}$$

7 bodova

$$P = \frac{U^2}{R} = \frac{U_{sr}{}^2 + U_v{}^2}{R} = \frac{U_{sr}{}^2 + \left(\frac{U_{vpp}}{2\sqrt{3}}\right)^2}{R} = 1{,}44W$$

10 bodova

2.

$$U_{BB} = U_{CC} \cdot \frac{R_2}{R_1 + R_2} = 7{,}55V \qquad R_{BB} = R_1 \| R_2 = 207{,}64k\Omega$$

$$I_{BQ} = \frac{U_{BB} - U_{BEQ}}{R_{BB} + (1+\beta) \cdot R_E} = 10{,}081\mu A$$

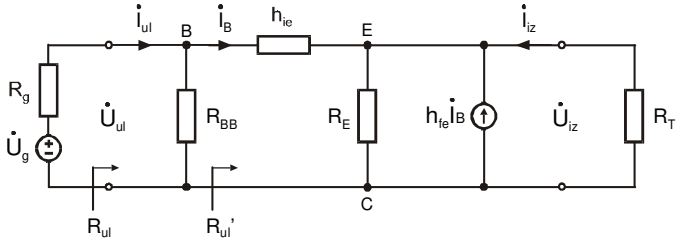
1 bod

$$I_{CQ} = \beta \cdot I_{BQ} = 1{,}21mA$$

2 boda

$$U_{CEQ} = U_{CC} - I_{CQ} \cdot R_E = 7{,}282V$$

3 boda



$$h_{ie} = \frac{mU_T}{I_{BQ}} = \frac{0{,}025}{I_{BQ}} = 2479{,}87\Omega \qquad A_V = \frac{\dot{U}_{iz}}{\dot{U}_{ul}} = \frac{(1+h_{fe}) \cdot R_E \| R_T}{h_{ie} + (1+h_{fe}) \cdot R_E \| R_T} = 0{,}7066$$

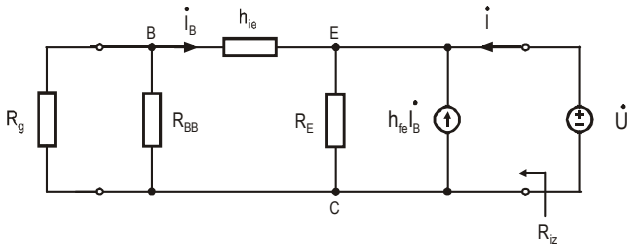
5 bodova

$$R_{ul} = R_{BB} \| R'_{ul}$$

$$R'_{ul} = \frac{\dot{U}_{ul}}{\dot{I}_B} = h_{ie} + (1+h_{fe}) \cdot R_E \| R_T = 8403{,}9\Omega \qquad R_{ul} = 8{,}08k\Omega$$

$$A_I = \frac{\dot{I}_{iz}}{\dot{I}_{ul}} = -\frac{\dot{U}_{iz}}{R_T} \cdot \frac{R_{ul}}{\dot{U}_{ul}} = -A_V \cdot \frac{R_{ul}}{R_T} = -114{,}15$$

7 bodova



$$R_{iz} = \frac{\dot{U}}{\dot{I}}$$

$$\dot{I} = -(\dot{I}_1 + \dot{I}_2 + \dot{I}_3)$$

$$\dot{I} = -\left(-\frac{\dot{U}}{h_{ie} + R_g \| R_{BB}} - \frac{\dot{U}}{R_E} - \frac{\dot{U} \cdot h_{fe}}{h_{ie} + R_g \| R_{BB}} \right) \qquad R_{iz} = \frac{(h_{ie} + R_g \| R_{BB}) \cdot R_E}{h_{ie} + R_g \| R_{BB} + (1+h_{fe}) \cdot R_E}$$

$$R_{iz} = 83{,}8\Omega$$

10 bodova

3.

$$U_{GG} = U_{DD} \cdot \frac{R_2}{R_1 + R_2} = 1{,}624V\,, \qquad R_G = R_1 \| R_2 = 606{,}4k\Omega$$

$$U_{GG} = U_{GSQ} + R_S \cdot I_{DQ}\,, \qquad I_{DQ} = \frac{K}{2} \cdot \left(U_{GSQ} - U_{GS0}\right)^2$$

$$I_{DQ} = \frac{U_{GG} - U_{GSQ}}{R_S} = \frac{K}{2} \cdot {U_{GSQ}}^2 + \frac{K}{2} \cdot {U_{GS0}}^2 - K \cdot U_{GSQ} \cdot U_{GS0}$$

$${U_{GSQ}}^2 + U_{GSQ} \cdot \left(\frac{2}{K \cdot R_S} - 2 \cdot U_{GS0}\right) + {U_{GS0}}^2 - \frac{2 \cdot U_{GG}}{K \cdot R_S} = 0$$

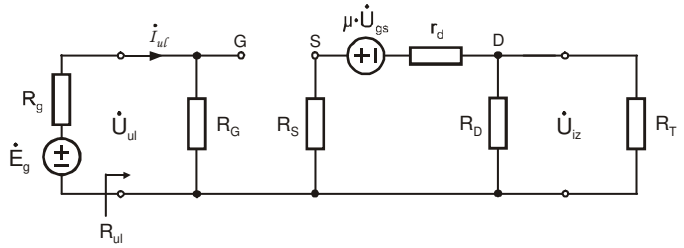
$${U_{GSQ}}^2 + 8{,}8369 U_{GSQ} + 4{,}3923 = 0$$

$U_{GSQ} = -0{,}529V$ Drugo se rješenje $U_{GSQ} = -8{,}31V$ odbacuje, jer tada FET ne vodi.

2 boda

$$I_{DQ} = 4{,}58mA\,, \qquad U_{DSQ} = U_{DD} - \left(R_S + R_D\right) \cdot I_{DQ} = 5{,}98V$$

3 boda



$$g_m = \frac{\partial I_D}{\partial U_{GS}} = K \cdot \left(U_{GSQ} - U_{GS0}\right) = 3{,}707\,\frac{mA}{V}\,, \qquad r_d = \frac{\mu}{g_m} = 21581\Omega$$

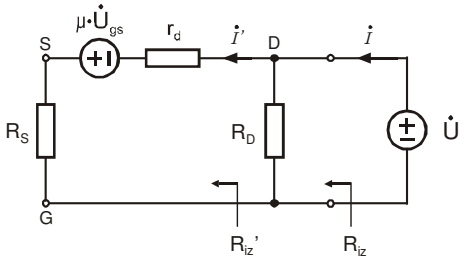
4 boda

$$A_V = \frac{\dot{U}_{iz}}{\dot{U}_{ul}} = -\frac{\mu \cdot R_D \| R_T}{r_d + R_D \| R_T + (1+\mu) \cdot R_S} = -1{,}903$$

6 bodova

$$R_{ul} = \frac{\dot{U}_{ul}}{\dot{I}_{ul}} = R_G = 606{,}4k\Omega$$

7 bodova



$$R_{iz} = \frac{\dot{U}}{\dot{I}} = R_D \| R_{iz}'$$

$$R_{iz}' = \frac{\dot{U}}{\dot{I}'} = \frac{\left(r_d + R_S\right) \cdot \dot{I}' - \mu \cdot \dot{U}_{gs}}{\dot{I}'}$$

$$\dot{U}_{gs} = -R_S \cdot \dot{I}'$$

$$R_{iz}' = r_d + (1+\mu) \cdot R_S = 59{,}65k\Omega$$

$$R_{iz} = 1463\Omega$$

10 bodova

4.

Zbog simetričnosti pojačala naponi i struje na oba su tranzistora jednaki.

$$U_{CC} + U_{EE} = I_{BQ} \cdot R_B + U_{BEQ} + 2 \cdot I_{BQ} \beta R_E$$

$$I_{BQ} = \frac{U_{CC} + U_{EE} - U_{BEQ}}{R_B + 2\beta R_E} = 29{,}68 \mu A$$

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2 boda

$$I_{CQ} = \beta I_{BQ} = 3{,}56 mA$$

$$U_{CEQ} = U_{CC} + U_{EE} - I_{CQ}(R_C + 2R_E) = 8{,}24 V$$

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4 bodova

$$h_{ie} = \frac{mU_T}{I_{BQ}} = \frac{0{,}025}{I_{BQ}} = 842{,}2\Omega$$

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5 bodova

$$A_{d1} = -A_{d2} = -\frac{h_{fe} \cdot R_C}{2h_{ie}} = -128{,}2$$

$$A_{z1} = A_{z2} = -\frac{h_{fe} \cdot R_C}{h_{ie} + 2 \cdot (1 + h_{fe}) \cdot R_E} = -1{,}885$$

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7 bodova

$$u_{iz1} = -|A_{d1}| \cdot (u_{ul1} - u_{ul2}) - |A_{z1}| \cdot \frac{u_{ul1} + u_{ul2}}{2} =$$

$$u_{iz1} = -256{,}472 \cdot 10^{-3} - 1{,}885 \cdot 10^{-3} = -258{,}357 mV$$

$$u_{iz2} = |A_{d2}| \cdot (u_{ul1} - u_{ul2}) - |A_{z2}| \cdot \frac{u_{ul1} + u_{ul2}}{2} =$$

$$u_{iz2} = 256{,}472 \cdot 10^{-3} - 1{,}885 \cdot 10^{-3} = 254{,}587 mV$$

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9 bodova

$$u_{iz1} - u_{iz2} = -512{,}9 mV$$

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10 bodova

5.

$$\dot{U}_{ul} = \dot{I}_{ul} \cdot \left(R_1 + \frac{1}{j\omega C_1} \right)$$

$$\dot{U}_{iz} = \dot{I}_{iz} \cdot \left(R_2 + \frac{1}{j\omega C_2} \right)$$

$$\dot{I}_{iz} = -\dot{I}_{ul}$$

$$A(j\omega) = \frac{\dot{U}_{iz}}{\dot{U}_{ul}} = -\frac{C_1}{C_2} \cdot \frac{1 + j\frac{\omega}{\omega_2}}{1 + j\frac{\omega}{\omega_1}}$$

$$\omega_1 = \frac{1}{R_1 C_1} = 45269 \frac{rad}{s} \qquad \omega_2 = \frac{1}{R_2 C_2} = 100 \frac{rad}{s}$$

4 boda

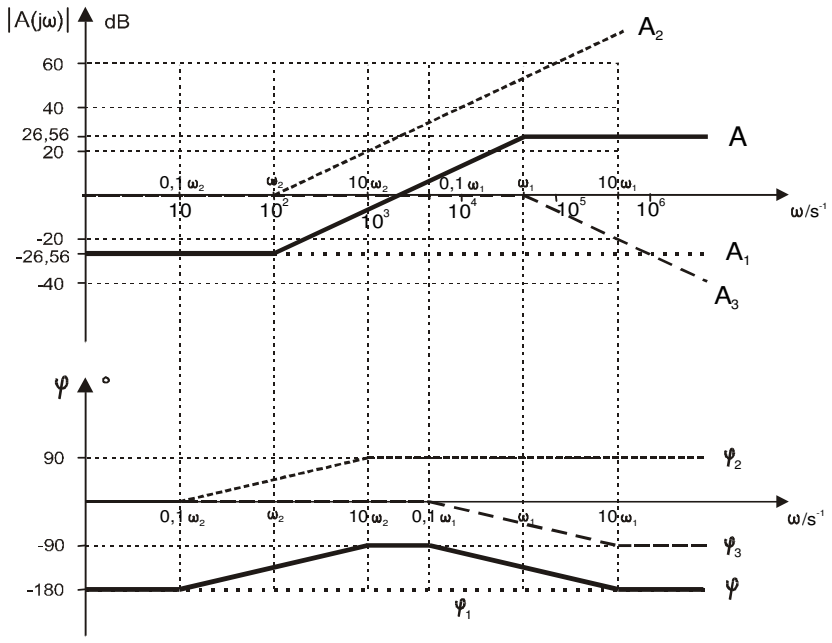
$$|A(j\omega)|_{dB} = 20\log\frac{C_1}{C_2} + 20\log\sqrt{1 + \left(\frac{\omega}{\omega_2}\right)^2} - 20\log\sqrt{1 + \left(\frac{\omega}{\omega_1}\right)^2} =$$

$$|A(j\omega)|_{dB} = -26{,}56 + 20\log\sqrt{1 + \left(\frac{\omega}{\omega_2}\right)^2} - 20\log\sqrt{1 + \left(\frac{\omega}{\omega_1}\right)^2} = A_1 + A_2 + A_3$$

6 bodova

$$\varphi = -180 + arctg\frac{\omega}{\omega_2} - arctg\frac{\omega}{\omega_1} = \varphi_1 + \varphi_2 + \varphi_3$$

8 bodova



10 bodova

Rješenja pismenog ispita iz Analognih sklopova održanog 4.2.2000.

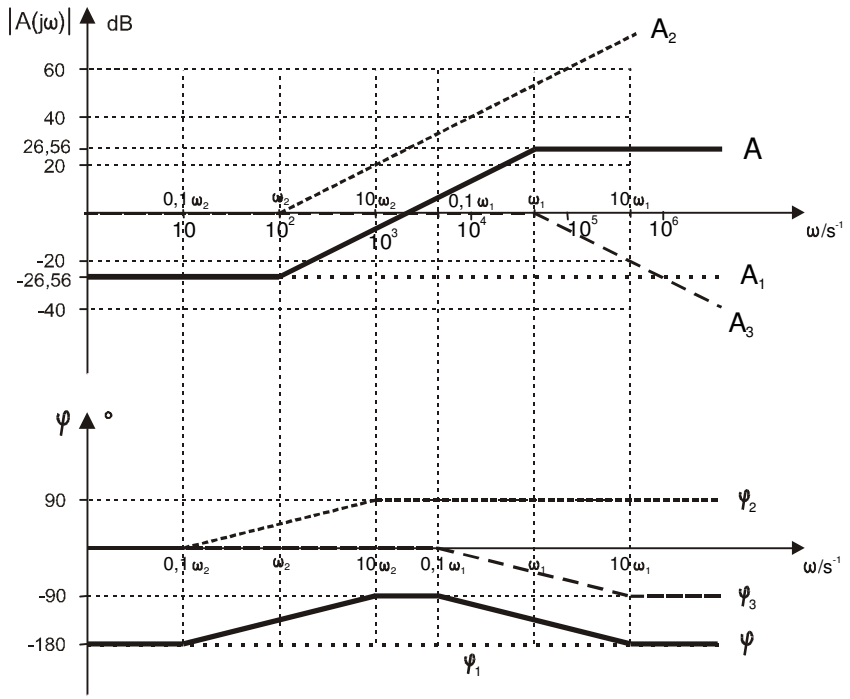
1. $C = 12{,}05mF$, $n = 25{,}8$, $r = 2{,}41 \cdot 10^{-3}$, $P = 1{,}44W$.

2. $I_{CQ} = 1{,}21mA$, $U_{CEQ} = 7{,}28V$, $A_V = 0{,}707$, $R_{ul} = 8077\Omega$, $A_I = -114{,}2$, $R_{iz} = 83{,}8\Omega$.

3. $I_{DQ} = 4{,}58mA$, $U_{DSQ} = 5{,}98V$, $A_V = -1{,}90$, $R_{ul} = 606{,}4k\Omega$, $R_{iz} = 1463\Omega$.

4. $I_{CQ} = 3{,}56mA$, $U_{CEQ} = 8{,}24V$, $u_{iz1} = -258.4mV$, $u_{iz2} = 254{,}6mV$,
   $u_{iz1} - u_{iz2} = -512{,}9mV$.

5. $$|A(j\omega)|_{dB} = -26{,}56 + 20\log\sqrt{1+\left(\frac{\omega}{\omega_2}\right)^2} - 20\log\sqrt{1+\left(\frac{\omega}{\omega_1}\right)^2}$$
   $$\varphi = -180 + arctg\,\frac{\omega}{\omega_2} - arctg\,\frac{\omega}{\omega_1}$$



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