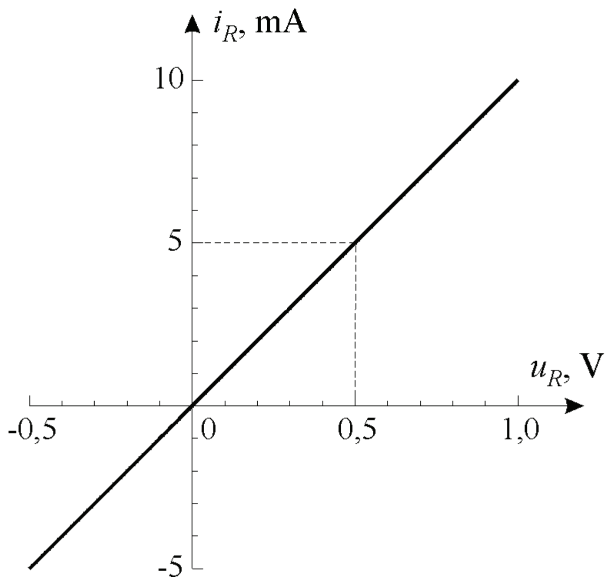
Fakultet elektrotehnike i računarstva
Zavod za elektroniku, mikroelektroniku,
računalne i inteligentne sustave

Elektronika 1

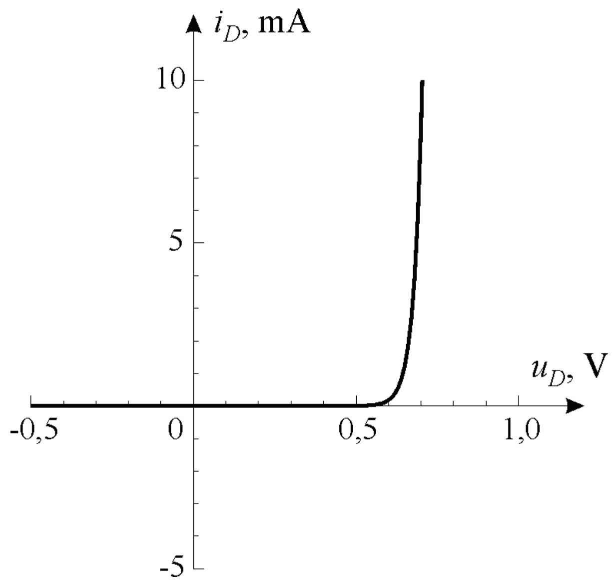
4. Sklopovi s diodom

Usporedba diode i otpornika

otpornik – 100 Ω



silicijska *pn*-dioda

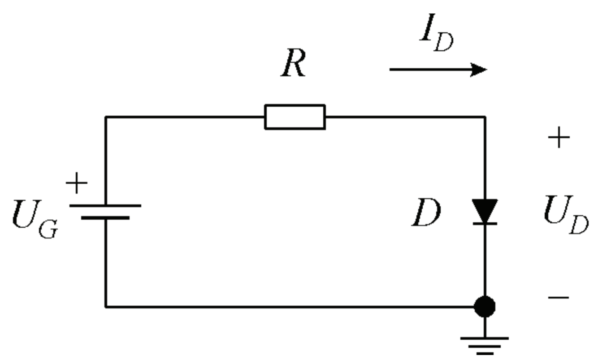


Specifičnost analize elektroničkih sklopova – zbog nelinearnih karakteristika elektroničkih elemenata

Statička analiza

Statičkom analizom proračunavaju se istosmjerne struje i naponi elektroničkih sklopova

Primjer sklopa



Iz strujnog kruga:

$$U_G = R\, I_D + U_D$$

Druga jednadžba:

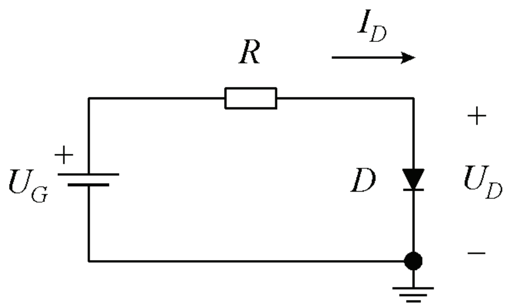
$$I_D = f(U_D)$$

npr. za propusnu polarizaciju

$$I_D = I_S \exp\,(U_D/U_T)$$

Primjer 4.1

Izračunati struju I_D i napon U_D za sklop prema slici. Napon $U_G = 3$ V, otpor $R = 500\ \Omega$, struja zasićenja diode $I_S = 10$ fF i temperatura je sobna, $U_T = 25$ mV.



Rješenje:

Uz $I_D = I_S \exp\left(U_D/U_T\right)$ $\qquad U_G = R\,I_S \exp\left(U_D/U_T\right) + U_D \qquad U_D = U_T \ln\left(\dfrac{U_G - U_D}{R\,I_S}\right)$

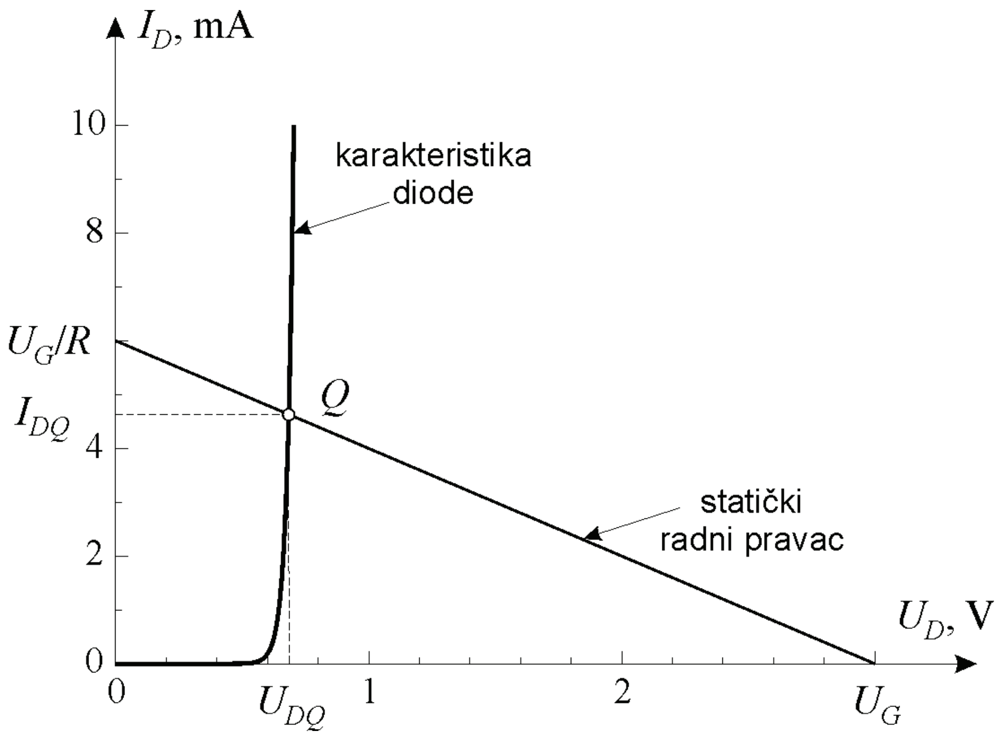
Iterativni postupak

$$\text{za } U_D = 0{,}7\text{ V} \quad \rightarrow \quad U_D = 0{,}025 \cdot \ln\left(\frac{3-0{,}7}{500 \cdot 10^{-15}}\right) = 0{,}671\text{ V}$$

$$\text{za } U_D = 0{,}671\text{ V} \quad \rightarrow \quad U_D = 0{,}025 \cdot \ln\left(\frac{3-0{,}671}{500 \cdot 10^{-15}}\right) = 0{,}672\text{ V}$$

$$I_D = \frac{U_G - U_D}{R} = \frac{3-0{,}672}{0{,}5} = 4{,}66\text{ mA}$$

Grafička analiza



Statički radni pravac:

$$U_G = R\,I_D + U_D$$

nagib - $-\,1/R$

Statička radna točka Q

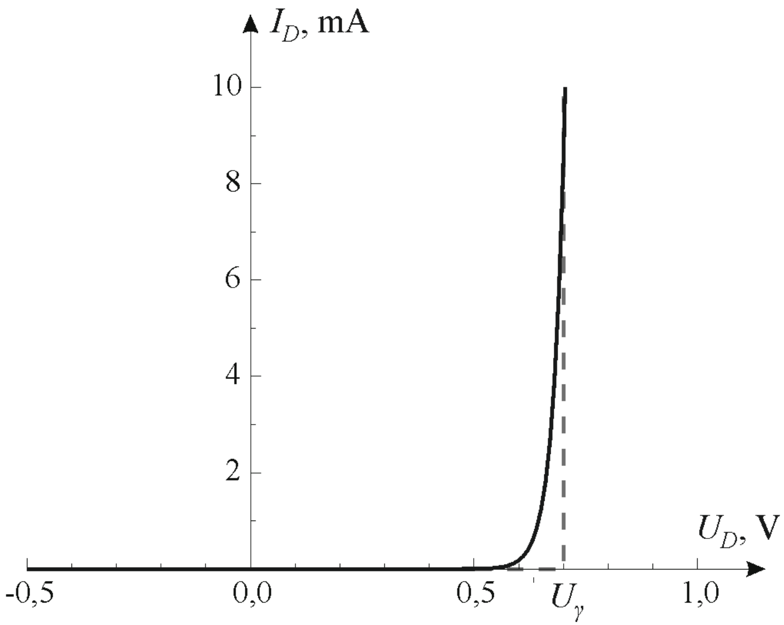
Primjer:

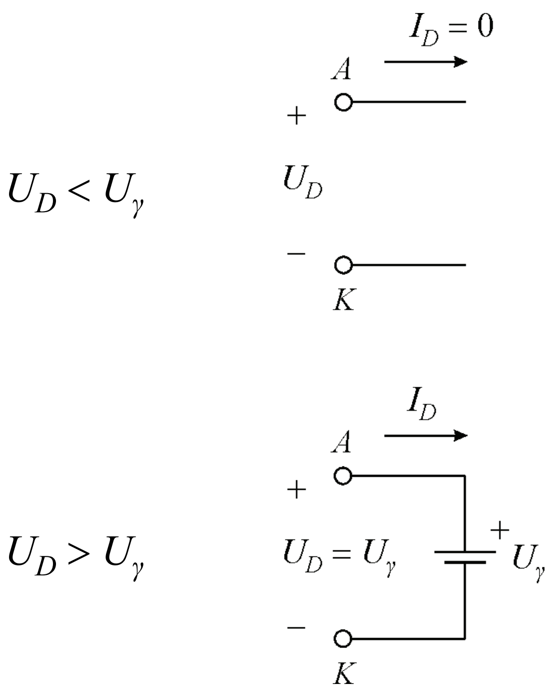
$$U_G = 3\text{ V},\ R = 500\ \Omega$$

$$U_{DQ} = 0{,}68\text{ V}$$

$$I_{DQ} = 4{,}6\text{ mA}$$

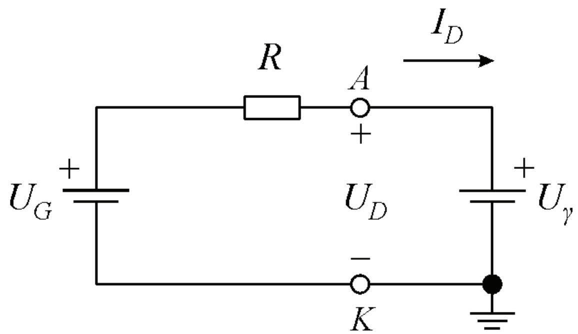
Model diode za statičku analizu





Analitički postupak – Primjer 4.2

Za $U_D > U_\gamma$



$$U_D = U_\gamma = U_{DQ}$$

$$I_D = \frac{U_G - U_\gamma}{R} = I_{DQ}$$

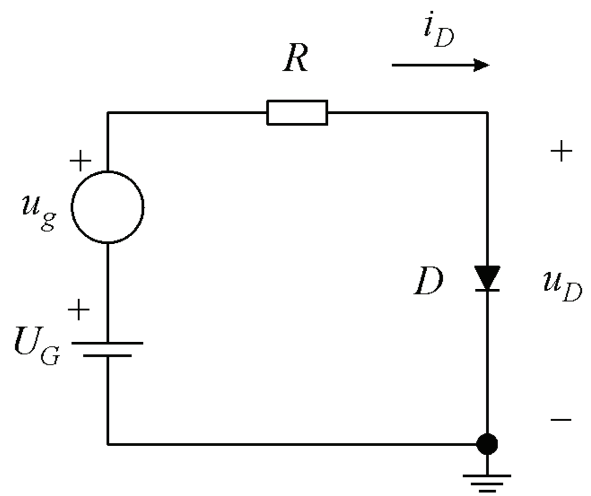
Primjer 4.2 - Ponoviti proračun struje i napona diode sklopa iz primjera 4.1 korištenjem modela diode za statičku analizu. Napon koljena diode $U_\gamma = 0{,}7\ \mathrm{V}$.

Rješenje:

$$U_{DQ} = U_\gamma = 0{,}7\ \mathrm{V} \qquad I_{DQ} = \frac{U_G - U_\gamma}{R} = \frac{3 - 0{,}7}{0{,}5} = 4{,}6\ \mathrm{mA}$$

Analiza uz priključak malog signala

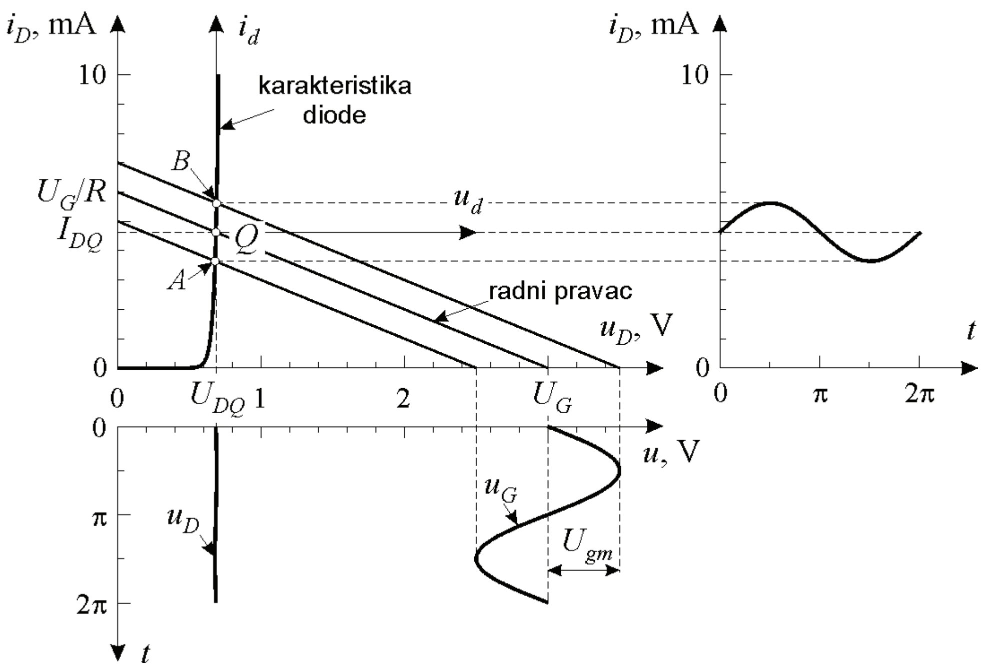
Primjer sklopa



Ulazni napon: $u_G = U_G + u_g = U_G + U_{gm} \sin \omega t$

Iz strujnog kruga: $u_G = R\, i_D + u_D$

Grafička analiza (1)



Radni pravac:

$$u_G = R\, i_D + u_D$$

pomiče se s primjenom u_G

Za mali signal

$$i_D = I_{DQ} + i_d = I_{DQ} + I_{dm} \sin \omega t$$

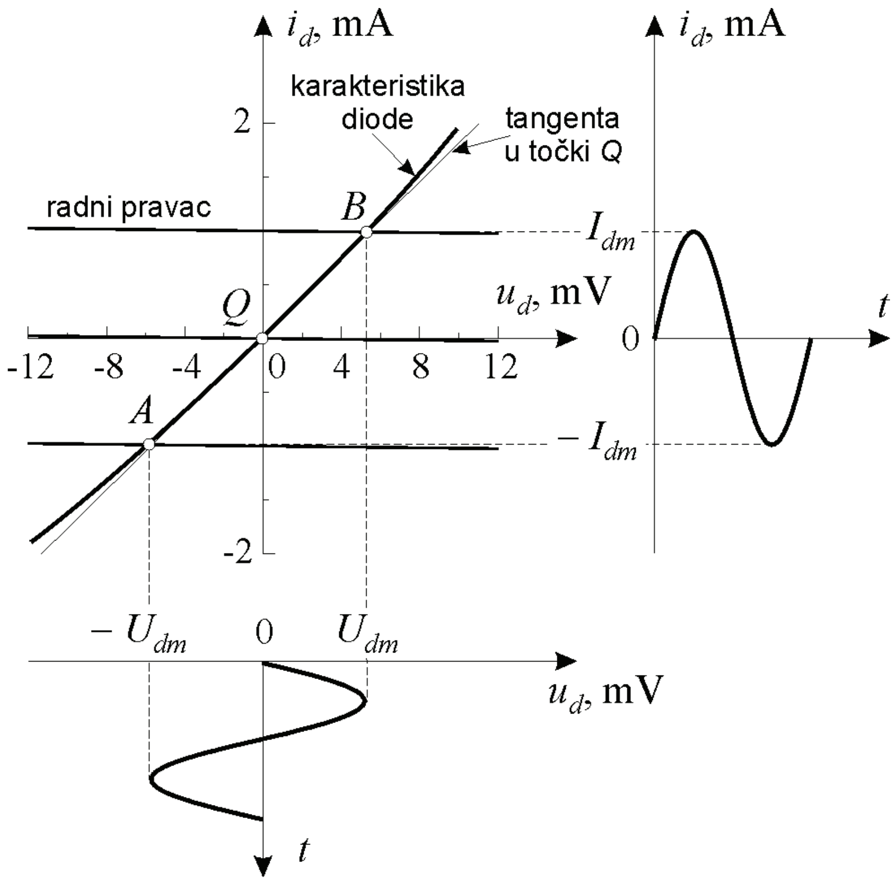
$$u_D = U_{DQ} + u_d = U_{DQ} + U_{dm} \sin \omega t$$

U statičkoj radnoj točki:

$$i_d = i_D - I_{DQ}$$

$$u_d = u_D - U_{DQ}$$

Grafička analiza (2)



Nagib karakteristike:

$$\left.\frac{\mathrm{d}i_D}{\mathrm{d}u_D}\right|_Q = \left.\frac{\Delta i_D}{\Delta u_D}\right|_Q = \frac{I_{dm}}{U_{dm}} = \frac{i_d}{u_d} = g_d$$

g_d – dinamička vodljivost

$r_d = 1/g_d$ – dinamički otpor

Primjer:

$U_{gm} = 0{,}5$ V

$I_{dm} = 1$ mA, $U_{dm} = 5{,}6$ mV

$g_d = 0{,}18$ S, $r_d = 5{,}6\ \Omega$

Uvjeti rada diode u režimu malog signala

Struja diode oko radne točke

$$i_D = i_D\big|_Q + \left.\frac{\mathrm{d}\,i_D}{\mathrm{d}\,u_D}\right|_Q (u_D - U_{DQ}) + \left.\frac{\mathrm{d}^2\,i_D}{\mathrm{d}\,u_D^2}\right|_Q \frac{(u_D - U_{DQ})^2}{2!} + \cdots$$

Uz $i_D = I_S \exp\,(u_D/U_T)$

$$\left.\frac{\mathrm{d}\,i_D}{\mathrm{d}\,u_D}\right|_Q = \left.\frac{I_S}{U_T}\exp\left(\frac{u_D}{U_T}\right)\right|_Q = \frac{I_{DQ}}{U_T} \qquad \left.\frac{\mathrm{d}^2\,i_D}{\mathrm{d}\,u_D^2}\right|_Q = \left.\frac{I_S}{U_T^2}\exp\left(\frac{u_D}{U_T}\right)\right|_Q = \frac{I_{DQ}}{U_T^2}$$

$$\text{uz}\; u_D - U_{DQ} = u_d \;\rightarrow\; i_D = I_{DQ}\left[1 + \frac{u_d}{U_T} + \frac{1}{2!}\left(\frac{u_d}{U_T}\right)^2 + \cdots\right]$$

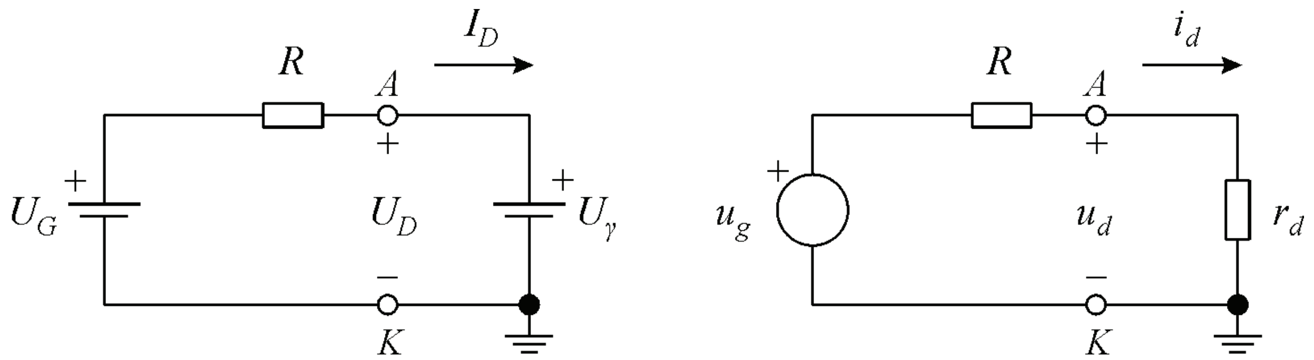
Uvjet za režim malog signala: $u_d << U_T$ $(U_{dm} << U_T)$

$$\left.\frac{\mathrm{d}\,i_D}{\mathrm{d}\,u_D}\right|_Q = \frac{I_{DQ}}{U_T} = g_d = \frac{1}{r_d} \qquad \text{uz linearni rad} \rightarrow i_D = I_{DQ} + i_d = I_{DQ} + \frac{u_d}{r_d}$$

Analitički postupak

Metoda superpozicije

uz: $u_G = U_G + u_g$ - analiza posebno za statiku, a posebno za dinamiku



statička analiza

dinamička analiza

$$U_D = U_\gamma = U_{DQ}$$

$$I_D = \frac{U_G - U_\gamma}{R} = I_{DQ}$$

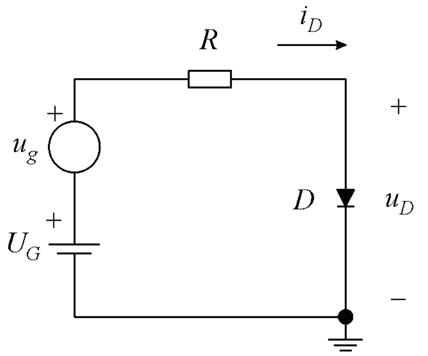
$$r_d = \frac{U_T}{I_{DQ}}$$

$$i_d = \frac{u_g}{R + r_d}$$

$$u_d = r_d \, i_d$$

Primjer 4.3

Za sklop sa slike analitički proračunati napon u_D i struju i_D diode.
Napon $u_G = 3 + 0{,}5\ \sin\omega t$ V, otpor $R = 500\ \Omega$, napon koljena diode $U_\gamma = 0{,}7$ V i temperatura je sobna, $U_T = 25$ mV.



Rješenje:

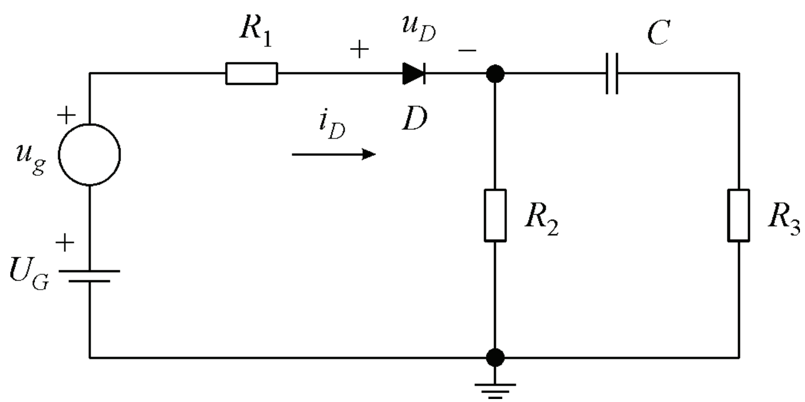
$$U_{DQ} = U_\gamma = 0{,}7\ \mathrm{V} \qquad I_{DQ} = \frac{U_G - U_\gamma}{R} = \frac{3 - 0{,}7}{0{,}5} = 4{,}6\ \mathrm{mA}$$

$$r_d = \frac{U_T}{I_{DQ}} = \frac{25}{4{,}6} = 5{,}43\ \Omega$$

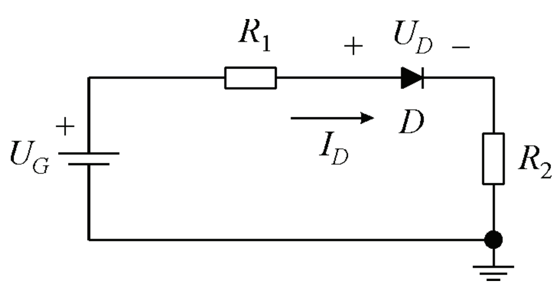
$$I_{dm} = \frac{U_{gm}}{R + r_d} = \frac{500}{500 + 5{,}43} = 0{,}989\ \mathrm{mA} \qquad U_{dm} = r_d\ I_{dm} = 5{,}43 \cdot 0{,}989 = 5{,}37\ \mathrm{mV}$$

$$i_D = 4{,}6 + 0{,}989 \sin\omega t\ \mathrm{mA} \qquad u_D = 700 + 5{,}37 \sin\omega t\ \mathrm{mV}$$

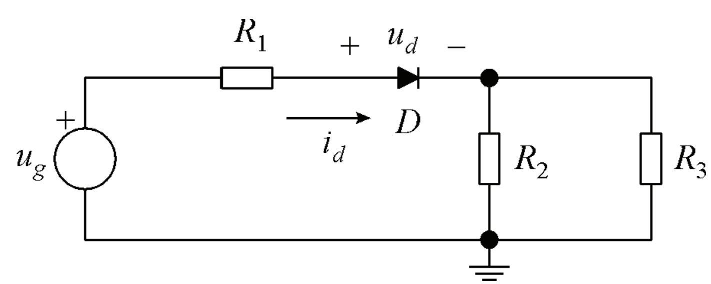
Utjecaj reaktivnih elemenata



Reaktivne komponente se različito ponašaju u statičkim i dinamičkim uvjetima.

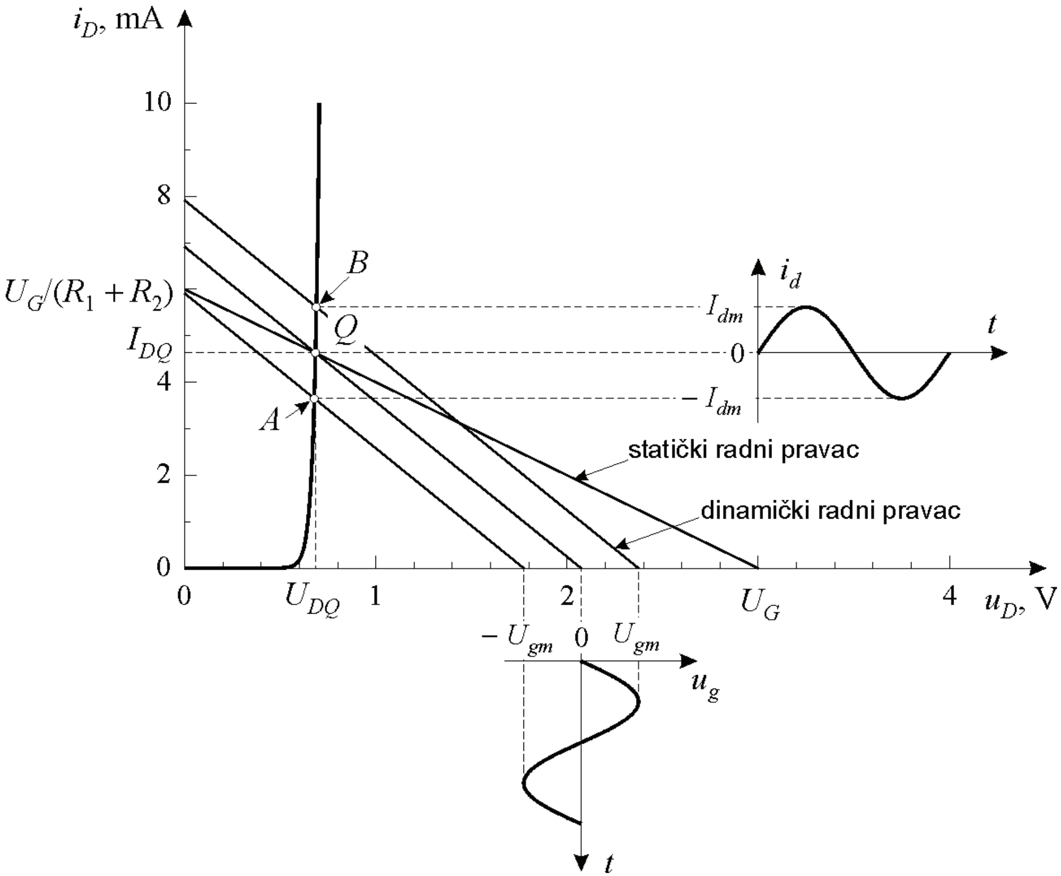


statička analiza



dinamička analiza

Grafička analiza



Statički radni pravac:

$$U_G = (R_1 + R_2)\, I_D + U_D$$

nagib: $-1/(R_1 + R_2)$

Dinamički radni pravac:

$$u_g = (R_1 + R_2\|R_3)\, i_d + u_d$$

nagib: $-1/(R_1 + R_2\|R_3)$

Primjer 4.4 (1)

Konstruirati statički radni pravac i dinamički radni pravac za napon $u_g = 0$ za primjer sa zadnjeg grafičkog prikaza. Zadano je: $U_G = 3$ V, $R_1 = 100\ \Omega$ i $R_2 = R_3 = 400\ \Omega$.

Rješenje:

Sjecišta s koordinatnim osima su:

os apscisa – $U_G = 3$ V,

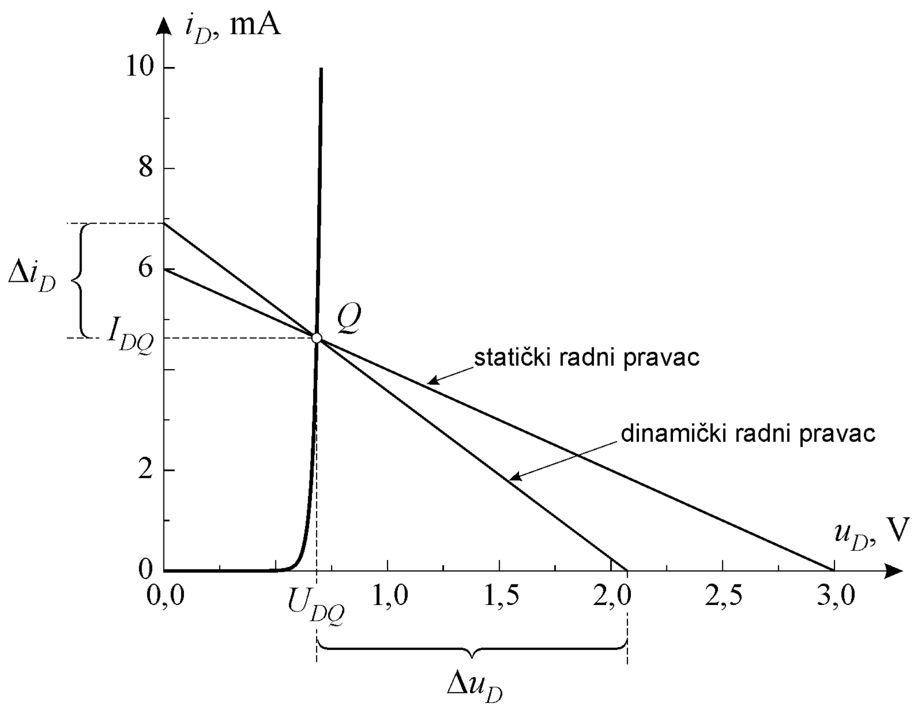
os ordinata – $U_G/(R_1 + R_2) = 3/(0{,}1 + 0{,}4) = 6$ mA

U statičkoj radnoj točki: $U_{DQ} = 0{,}68$ V, $I_{DQ} = 4{,}6$ mA

Otpor sklopa u dinamici:

$$R_{din} = R_1 + R_2 \| R_3 = 100 + 400 \| 400 = 300\ \Omega$$

Primjer 4.4 (2)



Za $u_g = 0$ dinamički radni pravac prolazi kroz točku Q

Uz nagib dinamičkog pravca $-1/R_{din}$

$$R_{din} = \frac{\Delta u_D}{I_{DQ}} = \frac{U_{DQ}}{\Delta i_D}$$

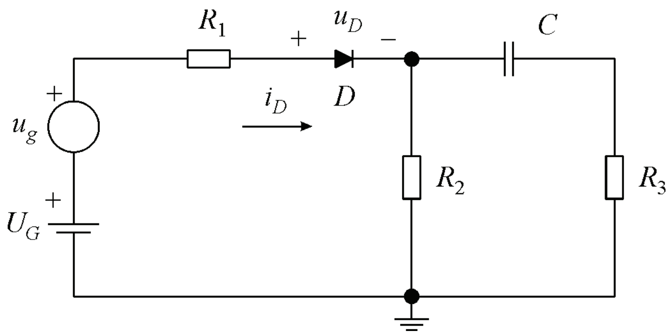
Sjecište s osi apsica

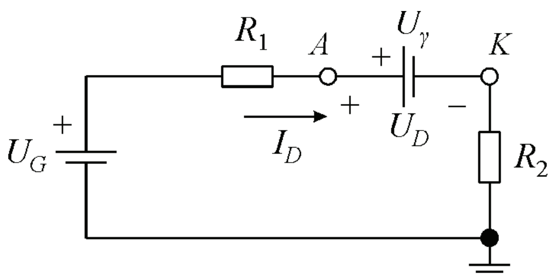
$$U_{DQ} + \Delta u_D = U_{DQ} + R_{din}\, I_{DQ} =$$
$$= 0{,}68 + 0{,}3 \cdot 4{,}6 = 2{,}06 \text{ V}$$

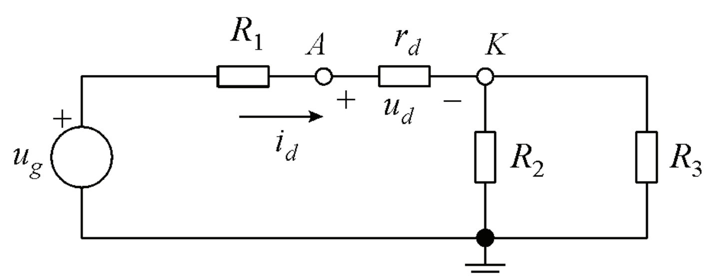
Sjecište s osi ordinata

$$I_{DQ} + \Delta i_D = I_{DQ} + U_{DQ} / R_{din} =$$
$$= 4{,}6 + 0{,}68 / 0{,}3 = 6{,}87 \text{ mA}$$

Analitički postupak







statička analiza

$$U_D = U_{DQ} = U_\gamma$$

$$I_D = I_{DQ} = \frac{U_G - U_\gamma}{R_1 + R_2}$$

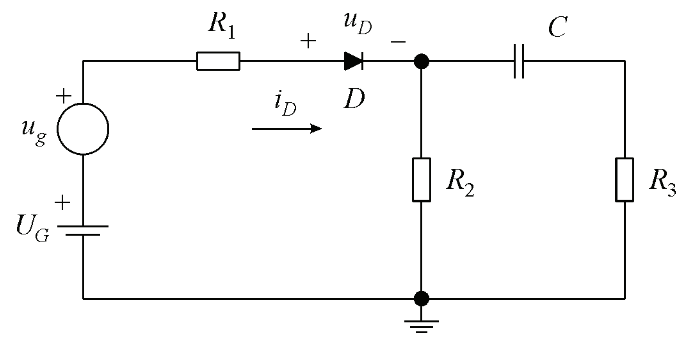
dinamička analiza

$$i_d = \frac{u_g}{R_1 + r_d + R_2 \| R_3}$$

$$u_d = r_d \, i_d$$

Primjer 4.5

Za sklop sa slike analitički proračunati napon u_D i struju i_D diode. Napon $u_G = 3 + 0{,}3\ \sin\omega t$ V, otpori $R_1 = 100\ \Omega$, $R_2 = R_3 = 400\ \Omega$, napon koljena diode $U_\gamma = 0{,}7$ V i temperatura je sobna, $U_T = 25$ mV.



Rješenje:

$$U_{DQ} = U_\gamma = 0{,}7\ \mathrm{V} \qquad I_{DQ} = \frac{U_G - U_\gamma}{R_1 + R_2} = \frac{3 - 0{,}7}{0{,}1 + 0{,}4} = 4{,}6\ \mathrm{mA}$$

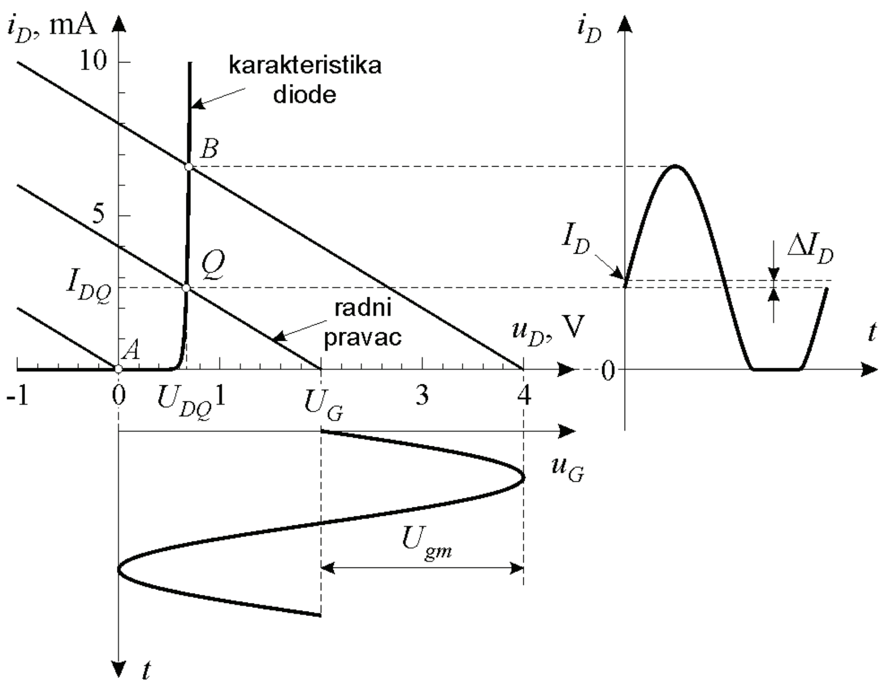
$$r_d = \frac{U_T}{I_{DQ}} = \frac{25}{4{,}6} = 5{,}43\ \Omega$$

$$I_{dm} = \frac{U_{gm}}{R_1 + r_d + R_2 \| R_3} = \frac{300}{100 + 5{,}43 + 400 \| 400} = 0{,}982\ \mathrm{mA}$$

$$U_{dm} = r_d\ I_{dm} = 5{,}43 \cdot 0{,}982 = 5{,}33\ \mathrm{mV}$$

$$i_D = 4{,}6 + 0{,}982 \sin \omega t\ \mathrm{mA} \qquad u_D = 700 + 5{,}33 \sin \omega t\ \mathrm{mV}$$

Priključak velikog signala



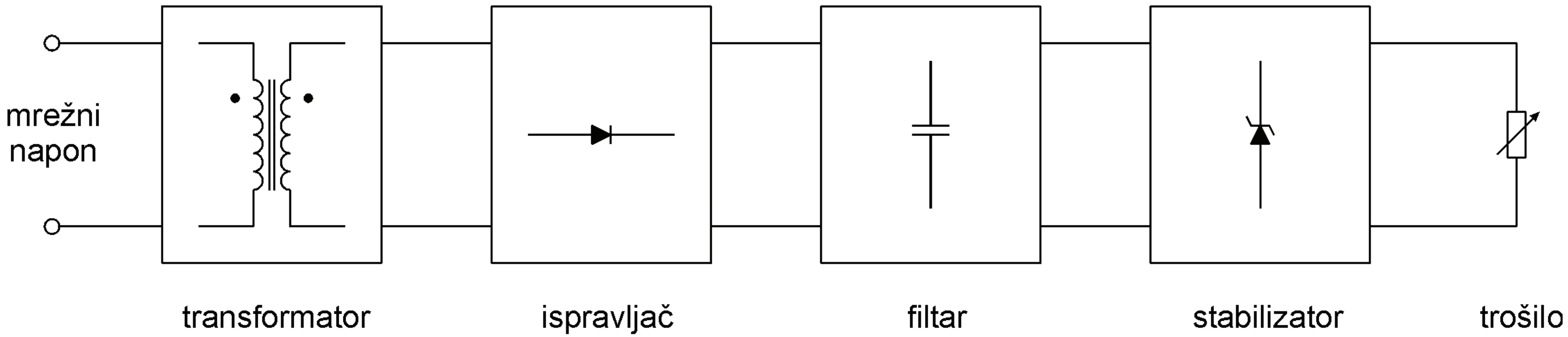
Hod radne točke po nelinearnom dijelu karakteristike

Posljedica nelinearnog rada:

- izobličenje struje
- dodatna istosmjerna struja ΔI_D

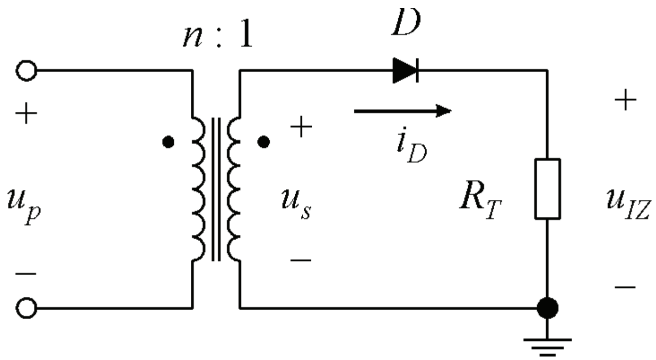
$$I_D = I_{DQ} + \Delta I_D$$

Izvor napajanja



- Mrežni napon – $f = 50\ \mathrm{Hz}$, $U_{pef} = 220\ \mathrm{V}$, $U_{pm} = 310\ \mathrm{V}$
- Transformator – smanjuje ulazni napon, izolira izvor od napona u primaru
- Ispravljač – ispravlja izmjenični napon, daje istosmjerni pulsirajući napon
- Filtar – guši izmjenične komponente
- Stabilizator – održava stalni istosmjerni napon
- Trošilo – elektronički sklopovi i uređaji

Polualni ispravljač (1)



Mrežni napon – $u_p = U_{pm} \sin \omega t$

Napon sekundara – $u_s = U_{sm} \sin \omega t$ Omjer transformacije: $n = U_{pm}/U_{sm}$

Za $u_D = u_s - u_{IZ} > U_\gamma$ $\rightarrow$ dioda vodi $\rightarrow$ $u_D = U_\gamma$, $u_{IZ} = u_s - U_\gamma$

Za $u_D < U_\gamma$ $\rightarrow$ dioda ne vodi $\rightarrow$ $i_D = 0$, $u_D = u_s$, $u_{IZ} = 0$

Polualni ispravljač (2)

Uz idealnu diodu:

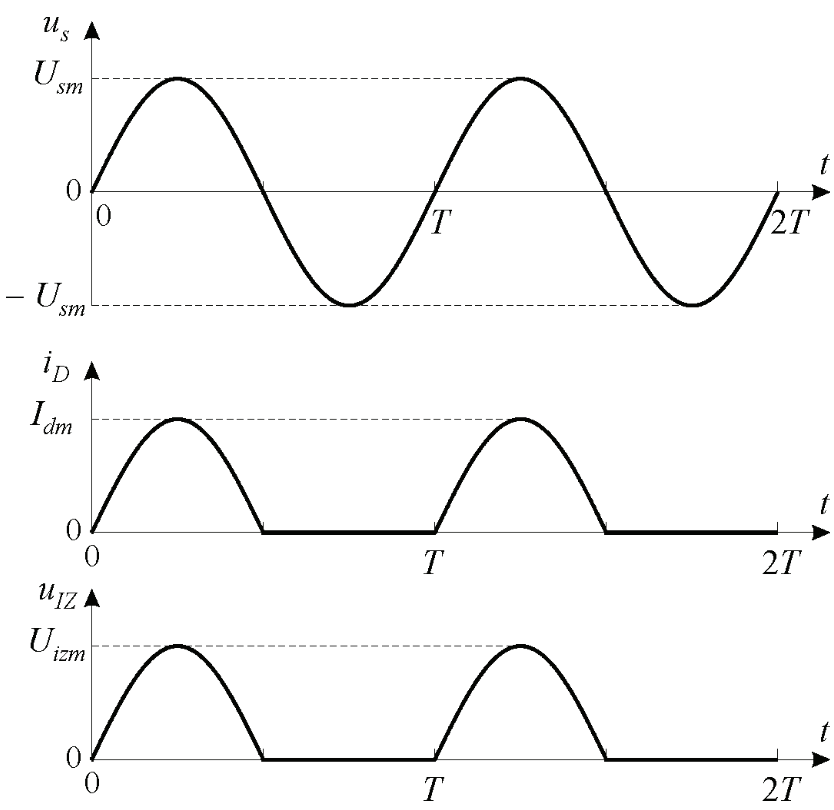
za $u_D < 0 \rightarrow i_D = 0$

za $u_D > 0 \rightarrow u_D = 0$

$$i_D = \begin{cases} u_s / R_T & \text{za} \quad u_s > 0 \\ 0 & \text{za} \quad u_s < 0 \end{cases}$$

$$u_{IZ} = i_D R_T$$

$$u_{IZ} = \begin{cases} u_s & \text{za} \quad u_s > 0 \\ 0 & \text{za} \quad u_s < 0 \end{cases}$$



Poluvalno ispravljeni napon (1)

Srednja vrijednost

$$U_{IZ} = \frac{1}{T}\int_0^T u_{IZ}(t)\,\mathrm{d}t = \frac{1}{2\pi}\left(U_{sm}\int_0^{\pi} \sin\omega t\,\mathrm{d}\omega t + \int_{\pi}^{2\pi} 0\,\mathrm{d}\omega t \right) = \frac{U_{sm}}{\pi} = 0{,}318\,U_{sm}$$

Efektivna vrijednost

$$U_{izef} = \left[\frac{1}{T}\int_0^T u_{IZ}^2(t)\,\mathrm{d}t \right]^{1/2} = \left[\frac{1}{2\pi}\left(U_{sm}^2\int_0^{\pi} \sin^2\omega t\,\mathrm{d}\omega t + \int_{\pi}^{2\pi} 0\,\mathrm{d}\omega t \right) \right]^{1/2} = \frac{U_{sm}}{2}$$

Razvojem poluvalno ispravljenog napona u Fourierov red

$$u_{IZ} = U_{sm}\left[\frac{1}{\pi} + \frac{\sin\omega t}{2} - \frac{2}{\pi}\left(\frac{\cos 2\omega t}{1\cdot 3} + \frac{\cos 4\omega t}{3\cdot 5} + \ldots \right) \right] = U_{IZ} + u_{izv}$$

Poluvalno ispravljeni napon (2)

Uz $U_{izef} = \sqrt{U_{IZ}^2 + U_{izvef}^2}$

Efektivna vrijednost napona valovitosti

$$U_{izvef} = \sqrt{U_{izef}^2 - U_{IZ}^2} = U_{sm}\sqrt{\frac{1}{4} - \frac{1}{\pi^2}} = 0{,}386\,U_{sm}$$

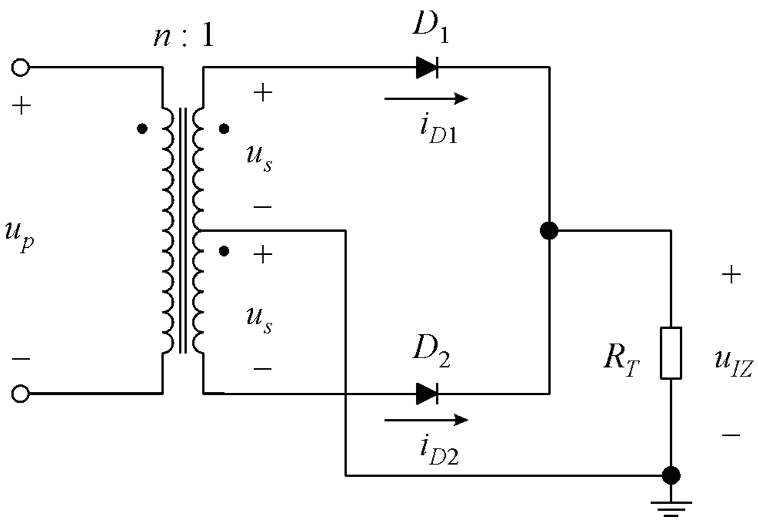
Faktor valovitosti

$$r = \frac{U_{izvef}}{U_{IZ}} = \sqrt{\left(\frac{U_{izef}}{U_{IZ}}\right)^2 - 1} = \sqrt{\frac{\pi^2}{4} - 1} = 1{,}21$$

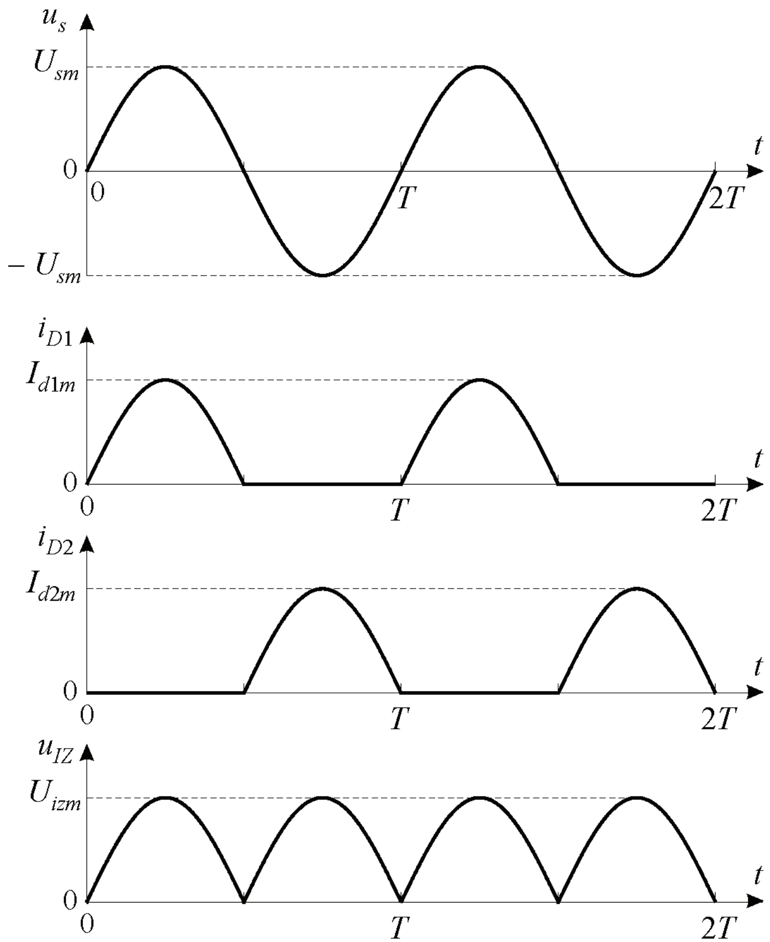
Maksimalna struja diode u vođenju – U_{sm}/R_T

Maksimalni zaporni napon diode – U_{sm}

Punovalni ispravljač



$$u_{IZ} = (i_{D1} + i_{D2})\, R_T$$



Punovalno ispravljeni napon (1)

Srednja vrijednost

$$U_{IZ} = \frac{2}{T}\int_0^{T/2} u_{IZ}(t)\,\mathrm{d}t = \frac{U_{sm}}{\pi}\int_0^{\pi} \sin\omega t\,\mathrm{d}\omega t = \frac{2U_{sm}}{\pi} = 0{,}637U_{sm}$$

Efektivna vrijednost

$$U_{izef} = \left[\frac{2}{T}\int_0^{T/2} u_{IZ}^2(t)\,\mathrm{d}t\right]^{\frac{1}{2}} = \left(\frac{U_{sm}^2}{\pi}\int_0^{\pi} \sin^2\omega t\,\mathrm{d}\omega t\right)^{\frac{1}{2}} = \frac{U_{sm}}{\sqrt{2}} = 0{,}707U_{sm}$$

Razvojem punovalno ispravljenog napona u Fourierov red

$$u_{IZ} = U_{sm}\left[\frac{2}{\pi} - \frac{4}{\pi}\left(\frac{\cos 2\omega t}{1\cdot 3} + \frac{\cos 4\omega t}{3\cdot 5} + \ldots\right)\right] = U_{IZ} + u_{izv}$$

Punovalno ispravljeni napon (2)

Efektivna vrijednost napona valovitosti

$$U_{izvef} = \sqrt{U_{izef}^2 - U_{IZ}^2} = U_{sm}\sqrt{\frac{1}{2} - \frac{4}{\pi^2}} = 0{,}308\,U_{sm}$$

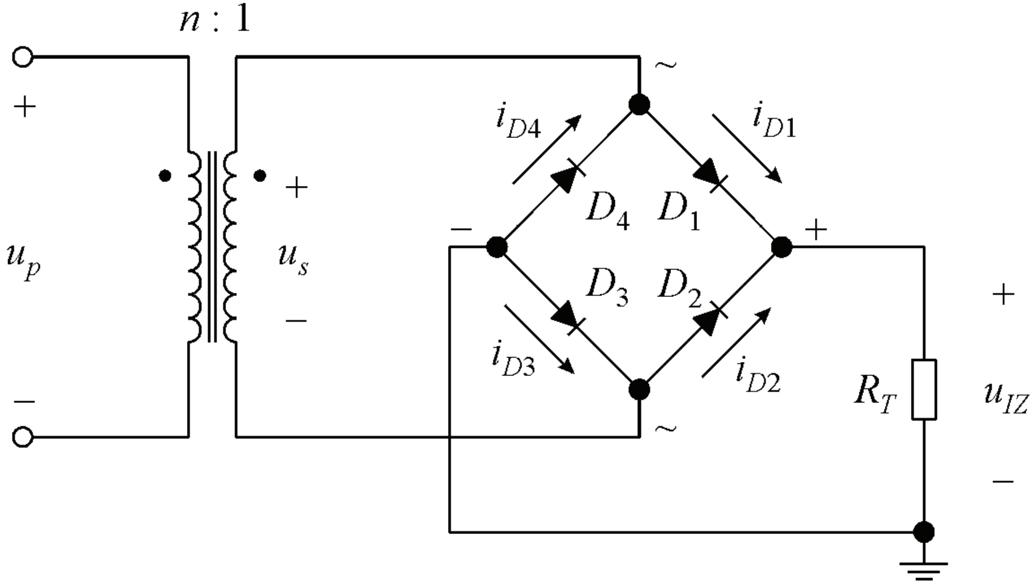
Faktor valovitosti

$$r = \frac{U_{izvef}}{U_{IZ}} = \sqrt{\left(\frac{U_{izef}}{U_{IZ}}\right)^2 - 1} = \sqrt{\frac{\pi^2}{8} - 1} = 0{,}483$$

Maksimalna struja dioda u vođenju – U_{sm}/R_T

Maksimalni zaporni napon dioda – $2U_{sm}$

Punovalni ispravljač – mosni ili Graetzov spoj

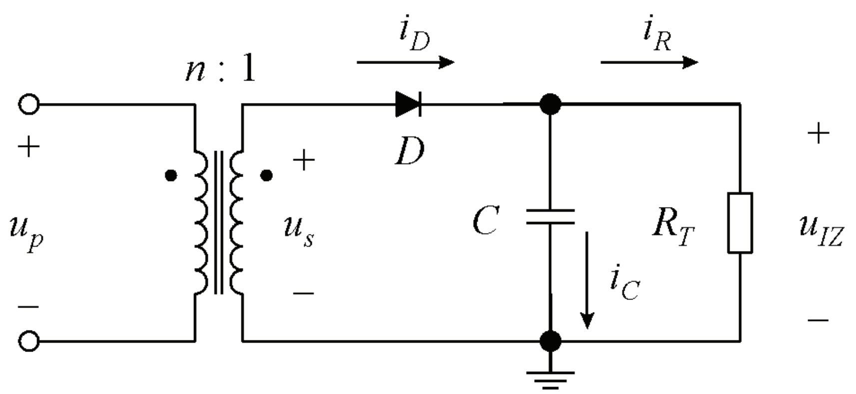


- Valni oblici – isti kao i kod prethodnog punovalnog ispravljača
- Maksimalna struja dioda u vođenju – U_{sm}/R_T
- Maksimalni zaporni napon dioda – U_{sm}
- Realizacija – sve 4 diode u istom kućištu

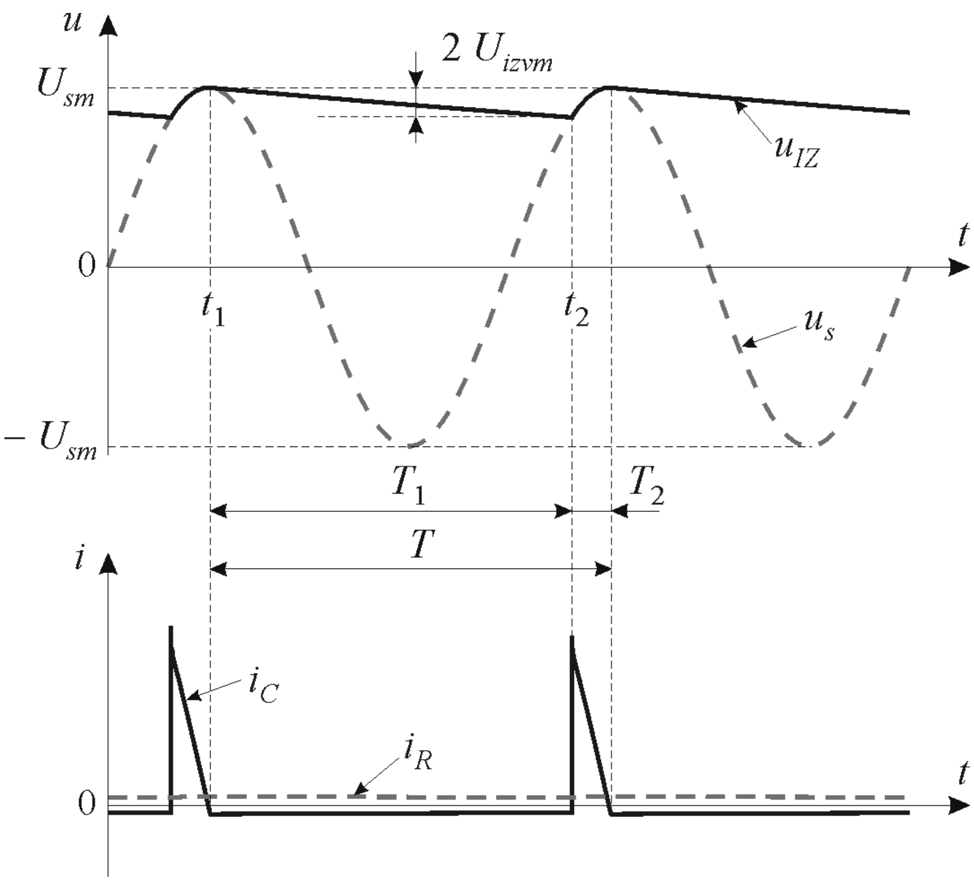
Ispravljač s kapacitivnim opterećenjem (1)

Smanjuje valovitost ispravljenog napona

C i R_T – niskopropusni filtar koji guši izmjenične komponente ispravljenog napona



Ispravljač s kapacitivnim opterećenjem (2)



Kroz $T_1 - u_s < u_{IZ}$ dioda ne vodi, kondenzator se izbija

$$u_{IZ}(t) = U_{sm} \exp\left(-\frac{t-t_1}{\tau}\right) \qquad \tau = R_T\, C$$

Za $t = t_2 - u_s = u_{IZ}$ dioda provede

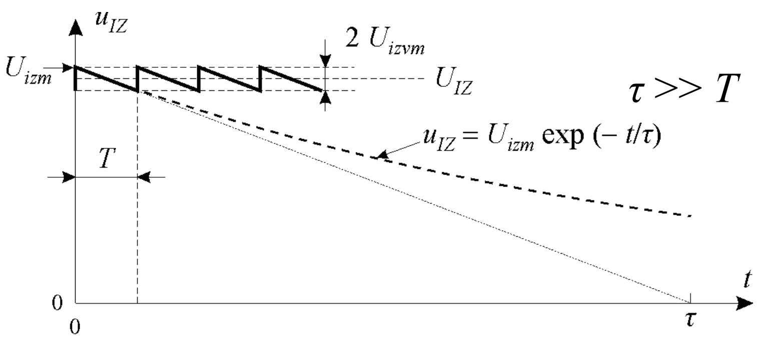
$$U_{sm} \cos\omega(t_2 - t_1) = U_{sm} \exp\left(-\frac{t_2 - t_1}{\tau}\right)$$

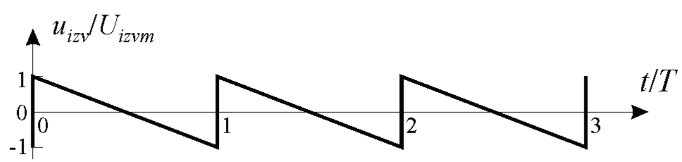
Kroz $T_2 - u_s = u_{IZ}$ dioda vodi, kondenzator se nabija

$$u_{IZ}(t) = u_s(t) = U_{sm} \cos\omega(t - t_1)$$

Maksimalni zaporni napon diode – $2U_{sm}$

Pojednostavljeni valni oblik napona trošila





Za $t = 0$ $\quad u_{IZ}(0) = U_{izm} = U_{sm}$

Za $t = T_2 \approx T$

$$u_{IZ}(T) = U_{izm}\exp\left(-\frac{T}{\tau}\right) \approx U_{izm}\left(1 - \frac{T}{\tau}\right)$$

$$u_{IZ}(0) - u_{IZ}(T) = 2U_{izvm}$$

$$U_{izvm} = U_{izm}\frac{T}{2\tau}$$

Srednja vrijednost $\quad U_{IZ} = u_{IZ} - u_{izv} = U_{izm} - U_{izvm} = U_{izm}\left(1 - \frac{T}{2\tau}\right)$

Izmjenični napon valovitosti $\quad u_{izv} = U_{izvm}\left(1 - \frac{2t}{T}\right)$ $\qquad U_{izvef} = \left[\frac{1}{T}\int_0^T u_{izv}^2(t)\,\mathrm{d}t\right]^{1/2} = \frac{U_{izvm}}{\sqrt{3}}$

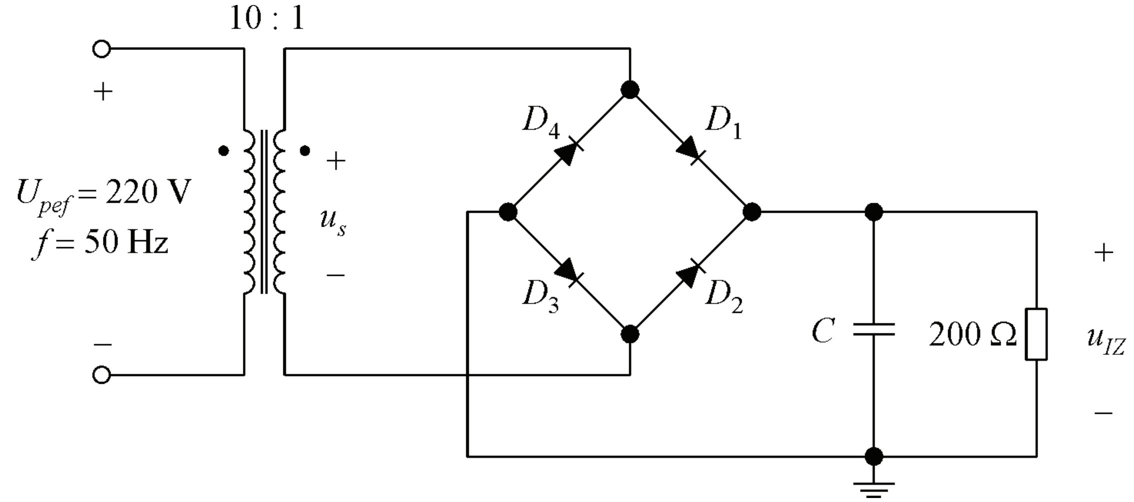
Faktor valovitosti $\quad r = \frac{U_{izvef}}{U_{IZ}} = \frac{T/(2\tau)}{\sqrt{3}\left[1 - T/(2\tau)\right]}$

Primjer 4.6 (1)

Za punovalni ispravljač u Graetzovim spoju s kapacitivnim opterećenjem na slici izračunati srednju vrijednost napona trošila i faktor valovitosti uz:

a) $C = 0$,

b) $C = 1000\ \mu\text{F}$.



Rješenje:

$$u_p = U_{pm} \sin \omega t \qquad U_{pm} = \sqrt{2}\, U_{pef} = \sqrt{2} \cdot 220 = 311\ \text{V}$$

$$u_s = U_{sm} \sin \omega t \qquad U_{sm} = U_{pm} / n = 311/10 = 31{,}1\ \text{V}$$

Primjer 4.6 (2)

a) $C = 0$

$$U_{IZ} = \frac{2U_{sm}}{\pi} = \frac{2 \cdot 31{,}1}{\pi} = 19{,}8\ \mathrm{V} \qquad U_{izef} = \frac{U_{sm}}{\sqrt{2}} = \frac{31{,}1}{\sqrt{2}} = 22\ \mathrm{V}$$

$$U_{izvef} = U_{sm}\sqrt{\frac{1}{2} - \frac{4}{\pi^2}} = 31{,}1 \cdot 0{,}308 = 9{,}58\ \mathrm{V} \qquad r = \frac{U_{izvef}}{U_{IZ}} = \frac{9{,}58}{19{,}8} = 0{,}483$$

b) $C = 1000\ \mu\mathrm{F}$

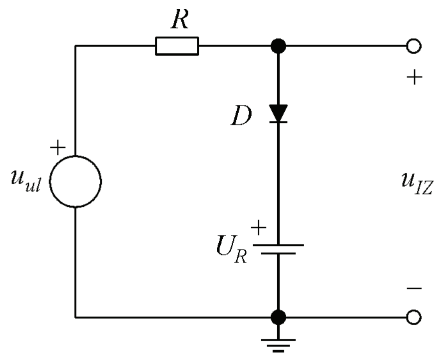
$$\tau = R_T\, C = 200 \cdot 1000 \cdot 10^{-6} = 200\ \mathrm{ms} \qquad T = 1/f = 1/50 = 20\ \mathrm{ms}$$

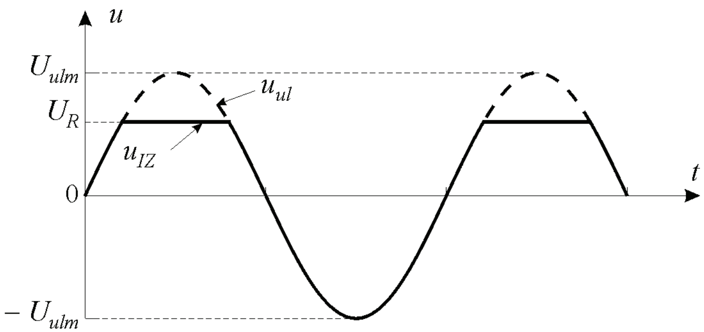
$$U_{izm} = U_{sm} = 31{,}1\ \mathrm{V}$$

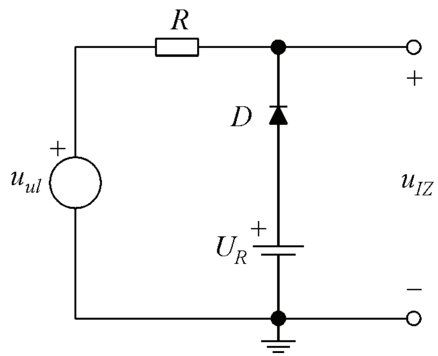
$$U_{izvm} = U_{izm}\frac{T}{4\tau} = 31{,}1 \cdot \frac{20}{4 \cdot 200} = 776\ \mathrm{mV} \qquad U_{IZ} = U_{izm} - U_{izvm} = 31{,}1 - 0{,}776 = 30{,}3\ \mathrm{V}$$

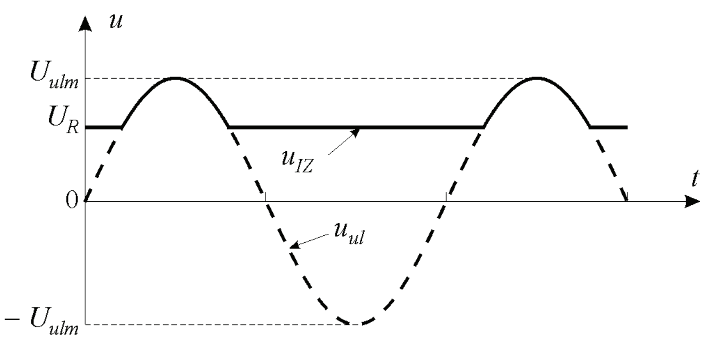
$$U_{izvef} = \frac{U_{izvm}}{\sqrt{3}} = \frac{776}{\sqrt{3}} = 448\ \mathrm{mV} \qquad r = \frac{U_{izvef}}{U_{IZ}} = \frac{0{,}448}{30{,}3} = 0{,}015$$

Paralelni diodni ograničavači (1)

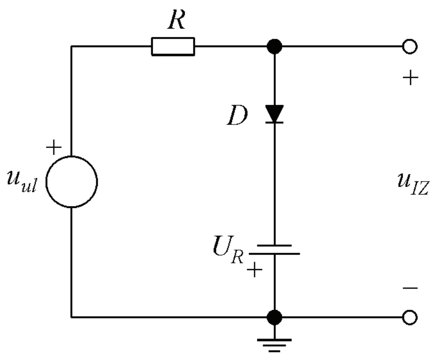


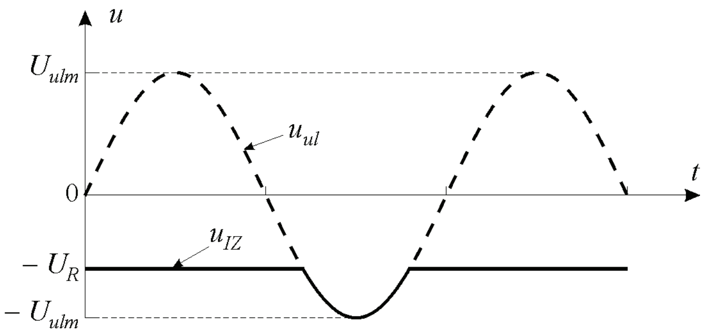


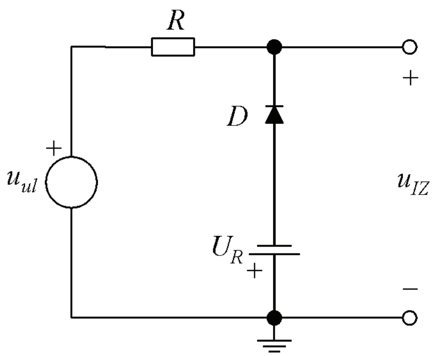


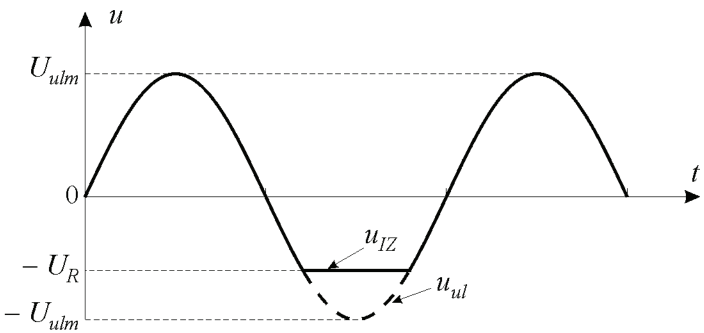


Paralelni diodni ograničavači (2)

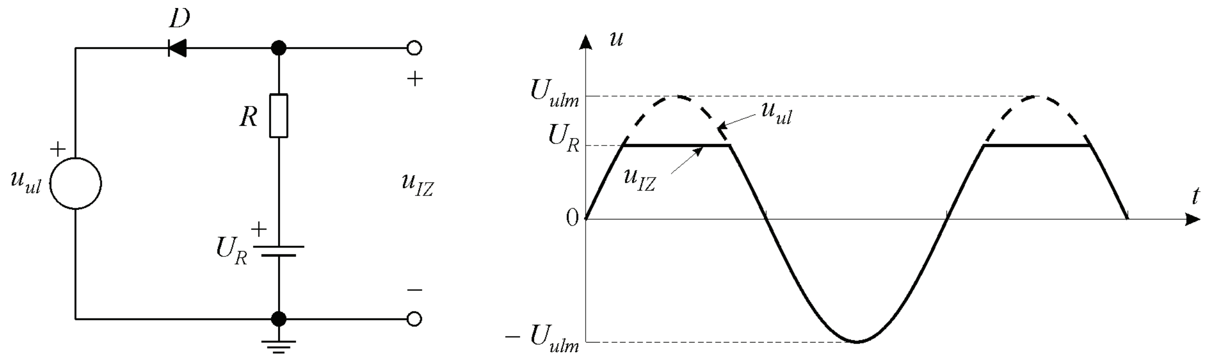








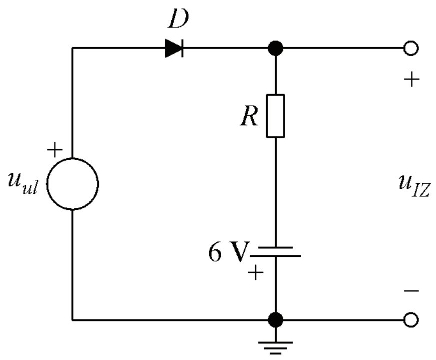
Serijski diodni ograničavač

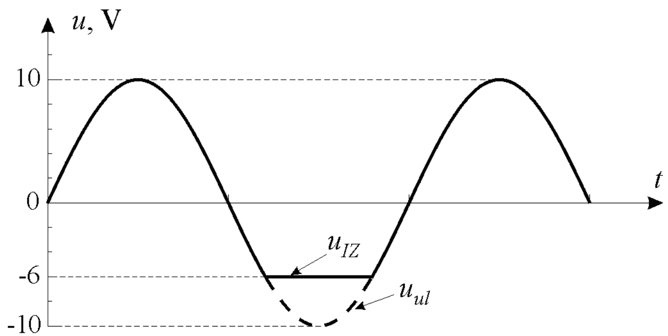


Primjer 4.7

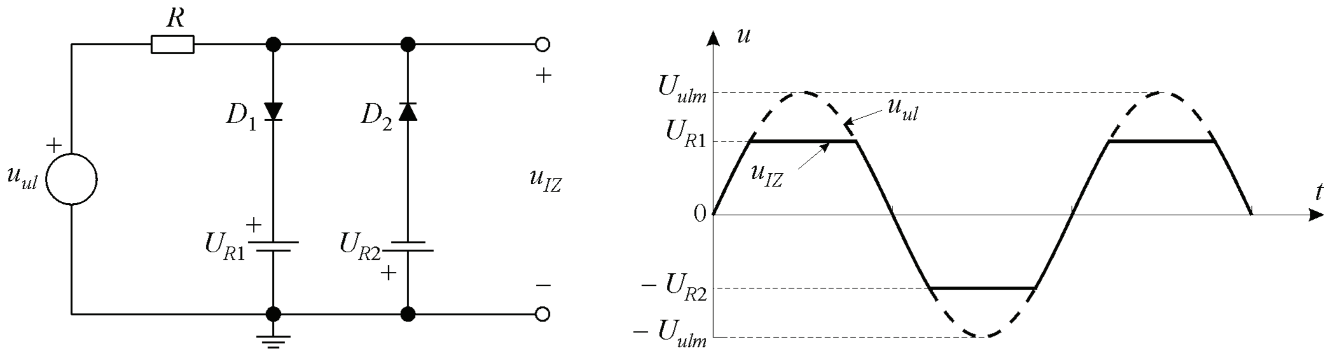
Nacrtati spoj serijskog diodnog ograničavača koji će ulazni napon $u_{ul} = 10 \sin \omega t$ V ograničiti ispod razine od -6 V.

Rješenje:

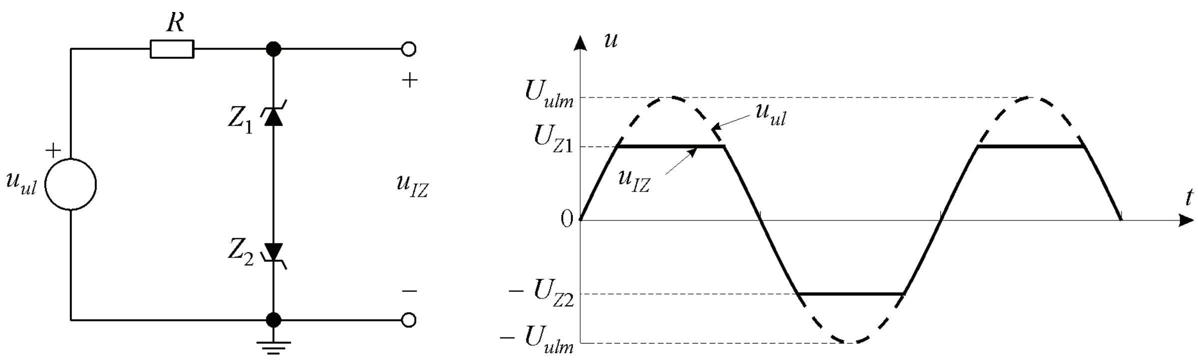




Dvostrani ograničavači



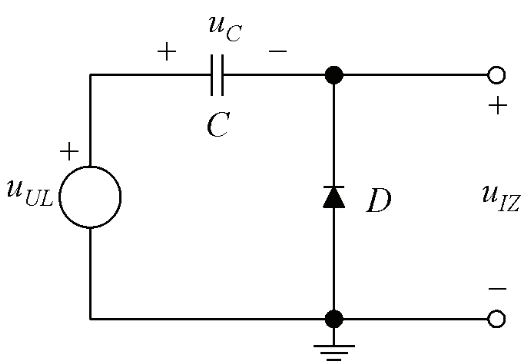
Dvostrani paralelni diodni ograničavač



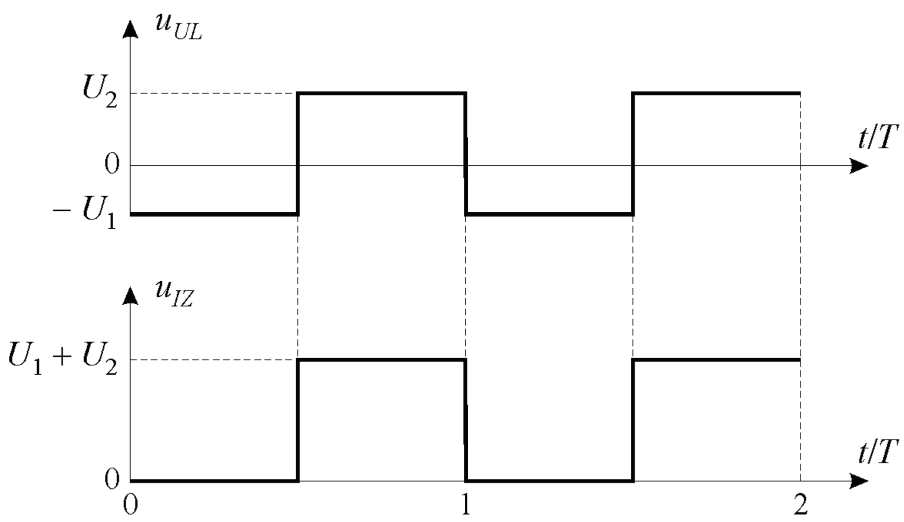
Dvostrani ograničavač sa Zenerovim diodama

Restauratori

Obnavljaju istosmjernu komponentu napona



$$u_C = u_{UL} - u_{IZ}$$



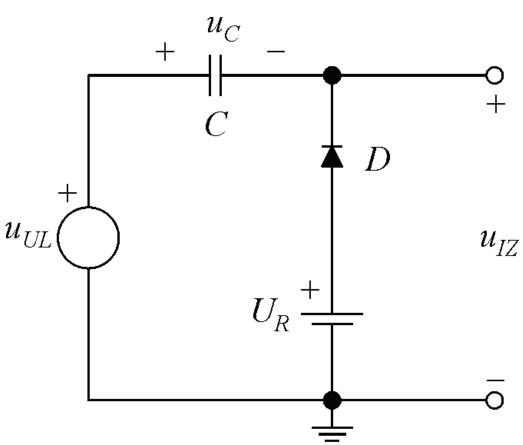
u $t = 0\_$ kondenzator je prazan

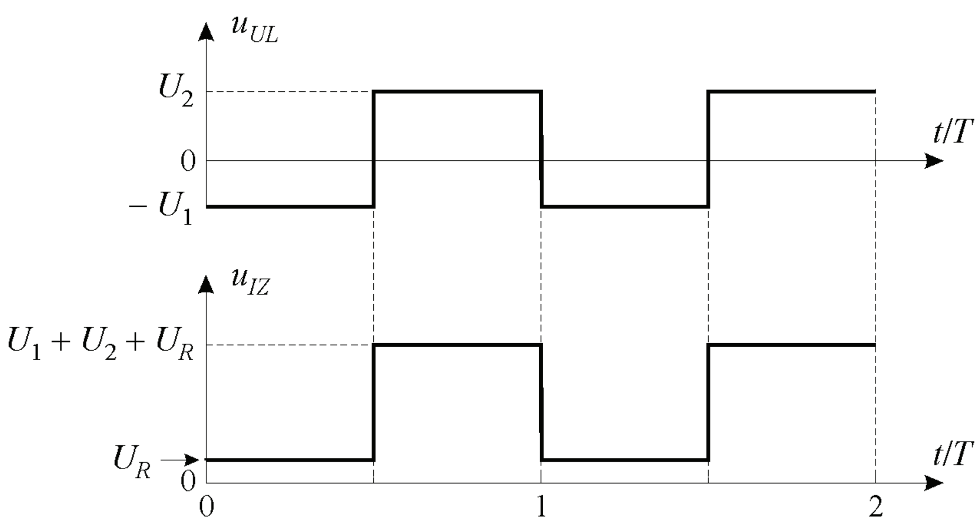
uz idealnu diodu u $0 < t < T/2$ dioda vodi i kondenzator se nabija na $u_C = -U_1$

za $t > T/2$ dioda više ne vodi, $u_C = -U_1$, $u_{IZ} = u_{UL} - u_C = u_{UL} + U_1$

Restaurator s dodadtim istosmjernim naponom

Dodatni pomak istosmjerne razine



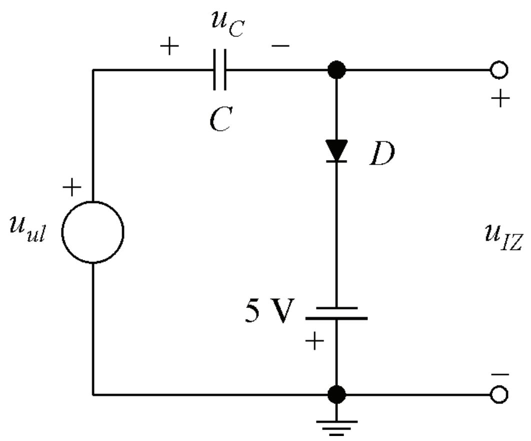


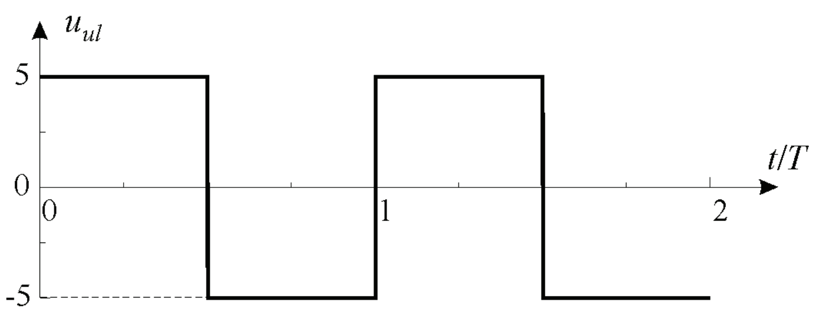
u $0 < t < T/2$ dioda vodi i kondenzator se nabija na $u_C = -U_1 - U_R$

za $t > T/2$ dioda više ne vodi, $u_C = -U_1 - U_R$, $u_{IZ} = u_{UL} - u_C = u_{UL} + U_1 + U_R$

Primjer 4.8 (1)

Za restaurator s priključenim ulaznim naponom u_{UL} prema slici odrediti valni oblik izlaznog napona u_{IZ}.





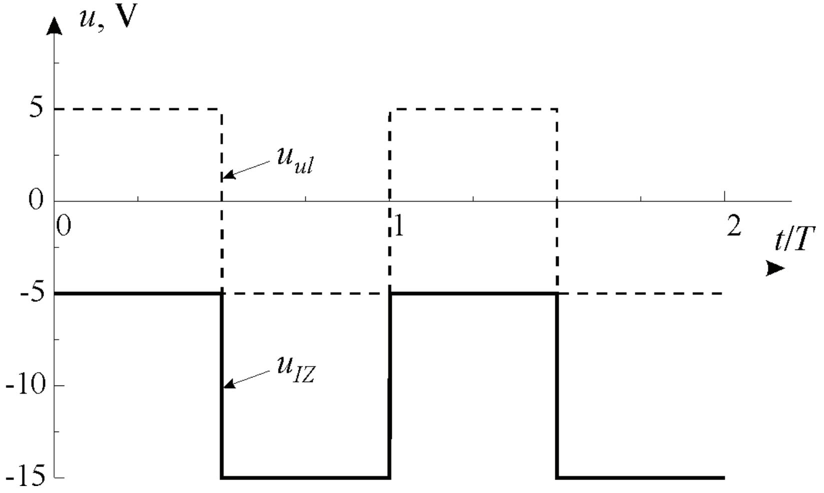
Rješenje:

u $0 < t < T/2$ dioda vodi i kondenzator se nabija na $u_C = u_{UL} + 5 = 5 + 5 = 10$ V, izlazni napon $u_{IZ} = u_{UL} - u_C = 5 - 10 = -5$ V

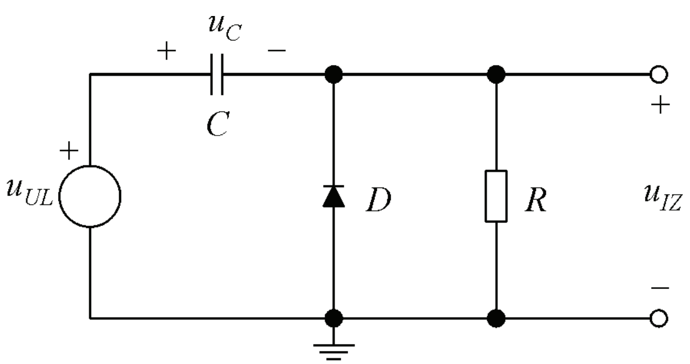
za $t > T/2$ dioda više ne vodi, $u_C = 10$ V, $u_{IZ} = u_{UL} - u_C = u_{UL} - 10$ V

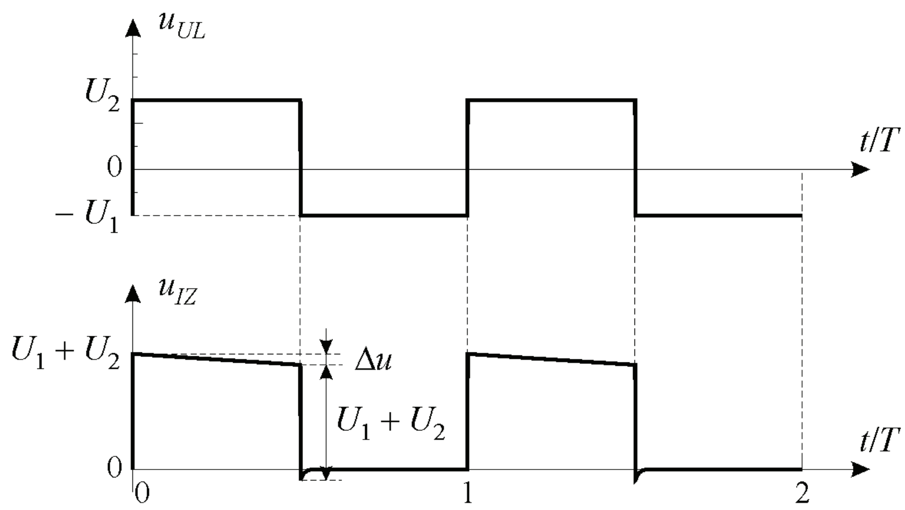
Primjer 4.8 (1)

Ulazni i izlazni napon



Restaurator opterećen otporom





u $t=0$ $u_C=-U_1$ dioda ne vodi, kondenzator se izbija preko R

nakon $t=T/2$ $\quad \Delta u=(U_1+U_2)\left[1-\exp\left(-\frac{T}{2\tau}\right)\right] \qquad \tau=RC$

u $t=T/2$ dioda se propusno polarizira i nabija kondenzator na $u_C=-U_1$ vremenskom konstantom $\tau_1=r_d\,C$