

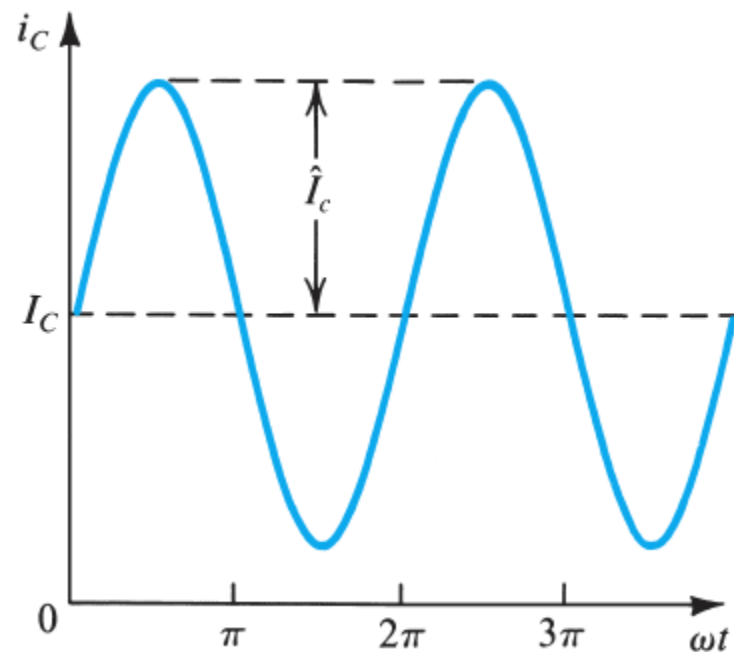
Osnove elektronike

III semestar

POJAČAVAČI SNAGE

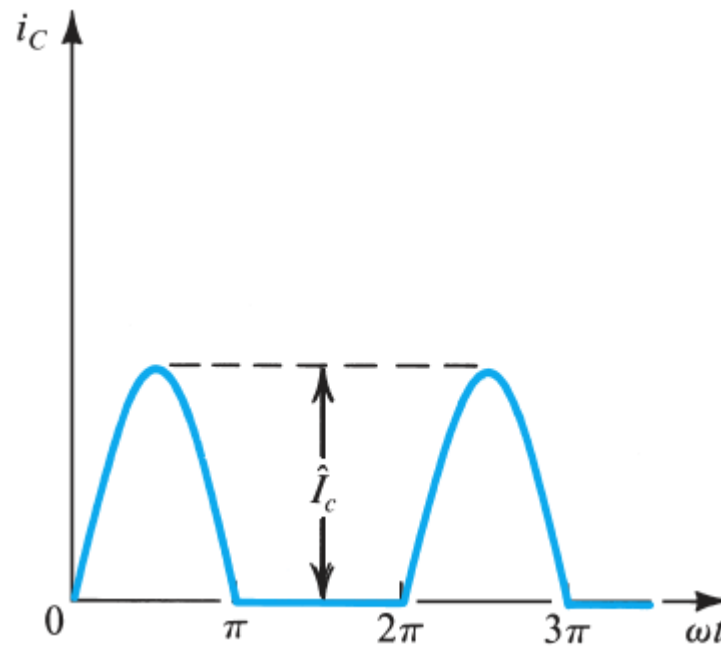
Pojačavač snage u klasi A

Tranzistor stalno vodi $2\pi \equiv 360^\circ$



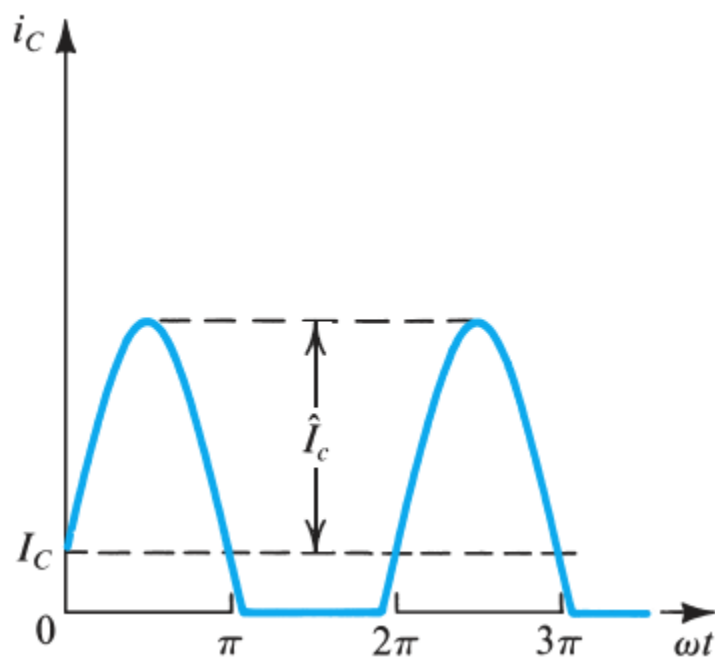
Pojačavač snage u klasi B

Svaki tranzistor vodi $\pi \equiv 180^\circ$



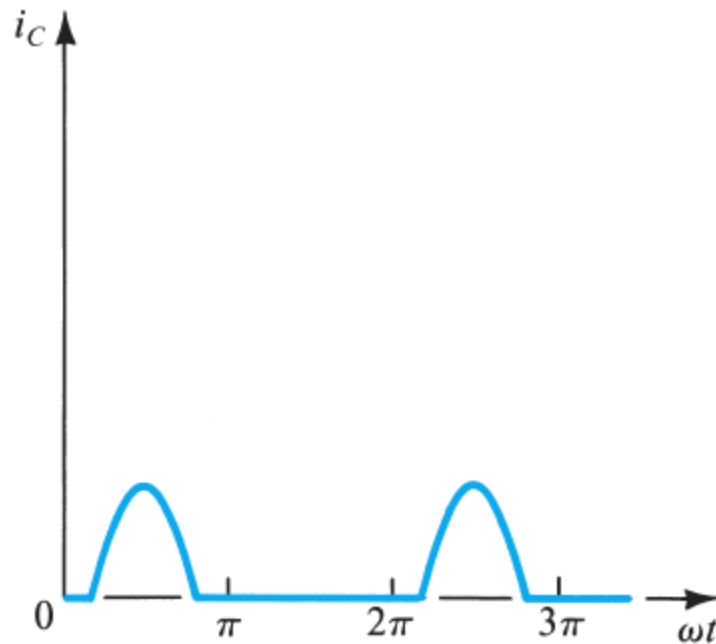
Pojačavač snage u klasi AB

Svaki tranzistor vodi više od $\pi \equiv 180^\circ$

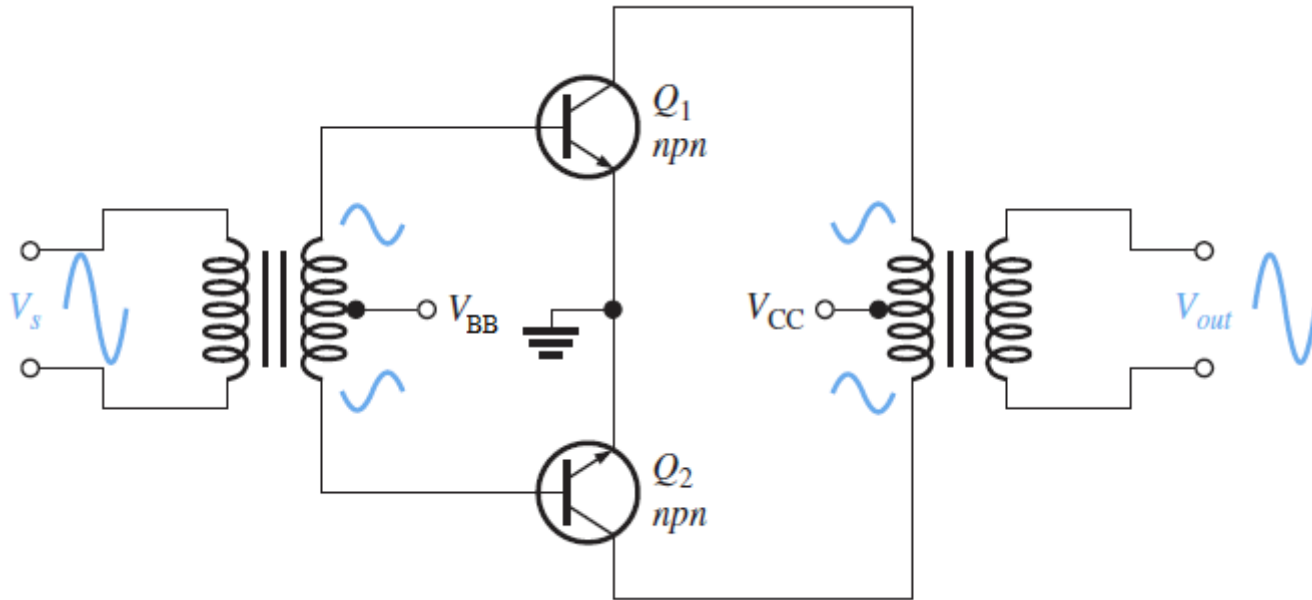


Pojačavač snage u klasi C

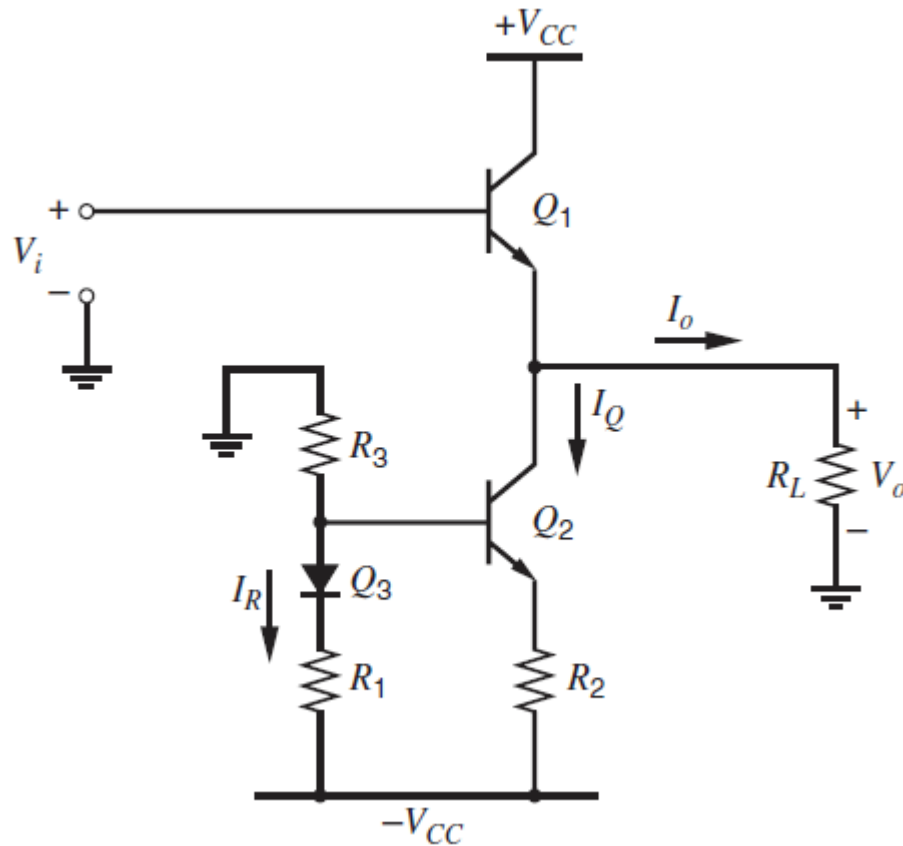
Tranzistor vodi manje od $\pi \equiv 180^\circ$ (za radio-frekventne pojačavače)



Simetrični pojačavač snage sa transformatorskom spregom u klasi A (istovremeno vode i Q_1 i Q_2)



Pojačavač snage sa zajedničkim kolektorom u klasi A (istovremeno vode i Q_1 i Q_2)



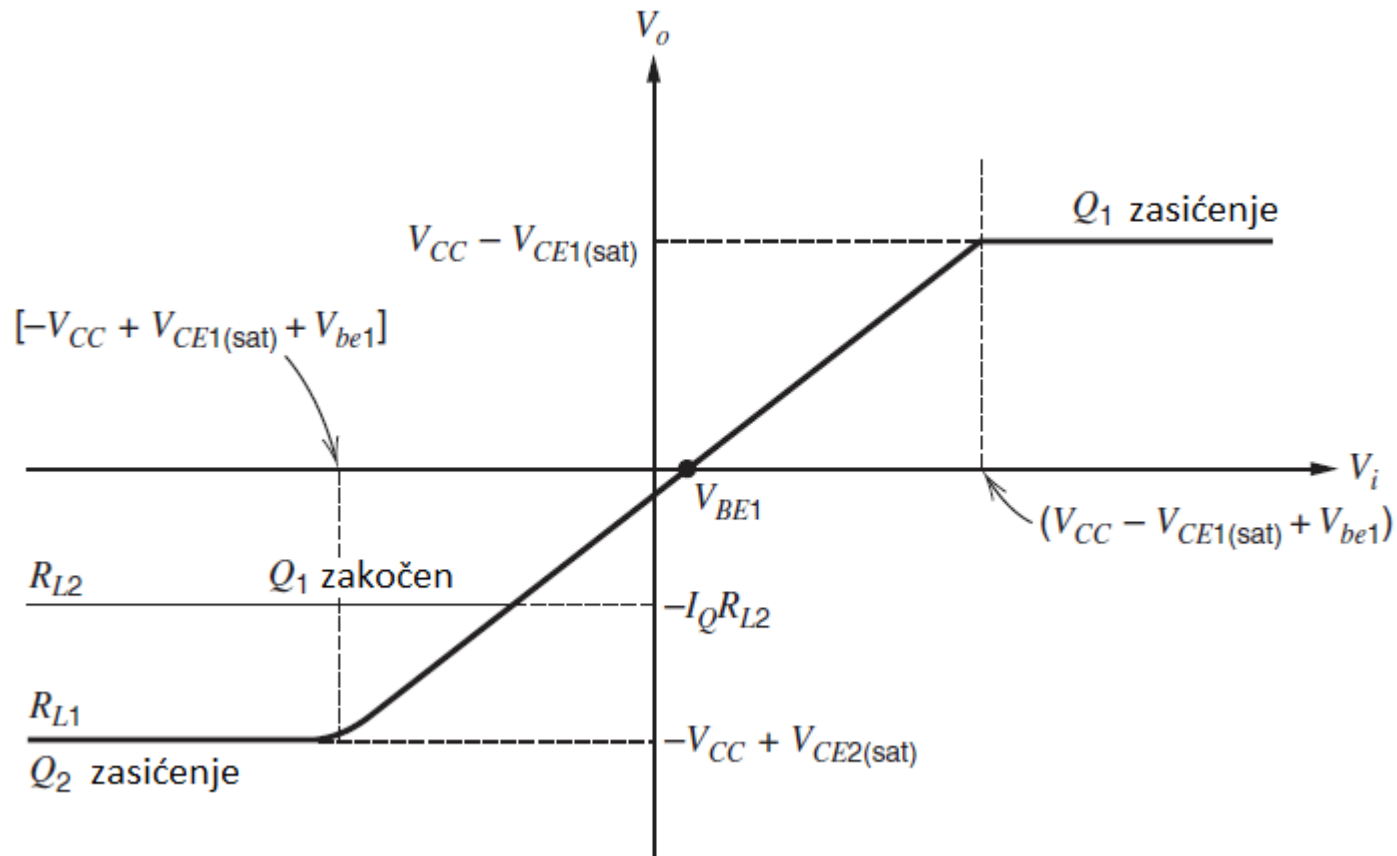
$$V_i = V_{be1} + V_o$$

$$V_{be1} = \frac{kT}{q} \ln \left(\frac{I_{c1}}{I_S} \right)$$

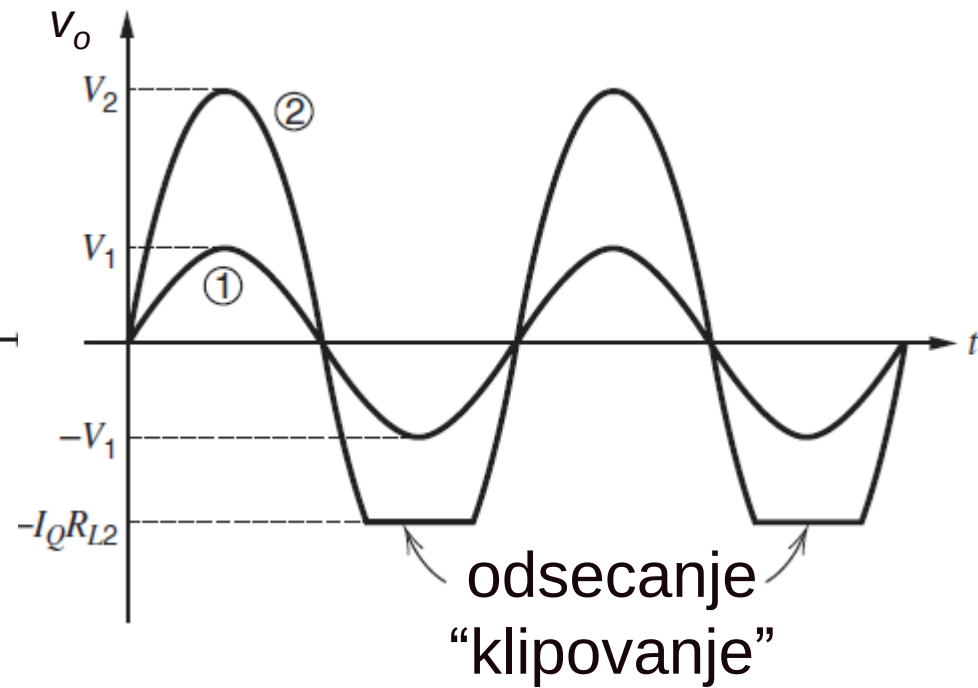
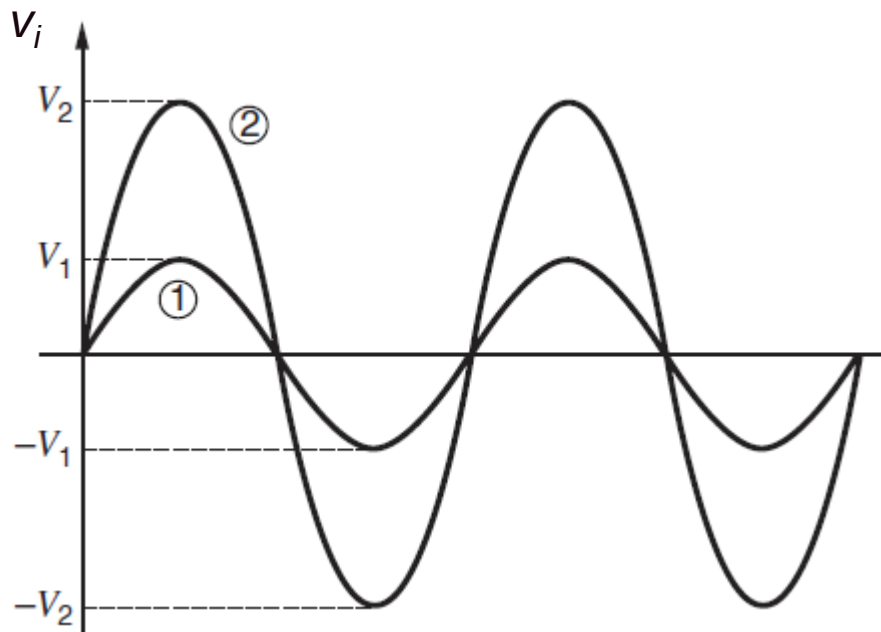
$$I_{c1} = I_Q + \frac{V_o}{R_L}$$

$$V_i = \frac{kT}{q} \ln \left(\frac{I_Q + \frac{V_o}{R_L}}{I_S} \right) + V_o$$

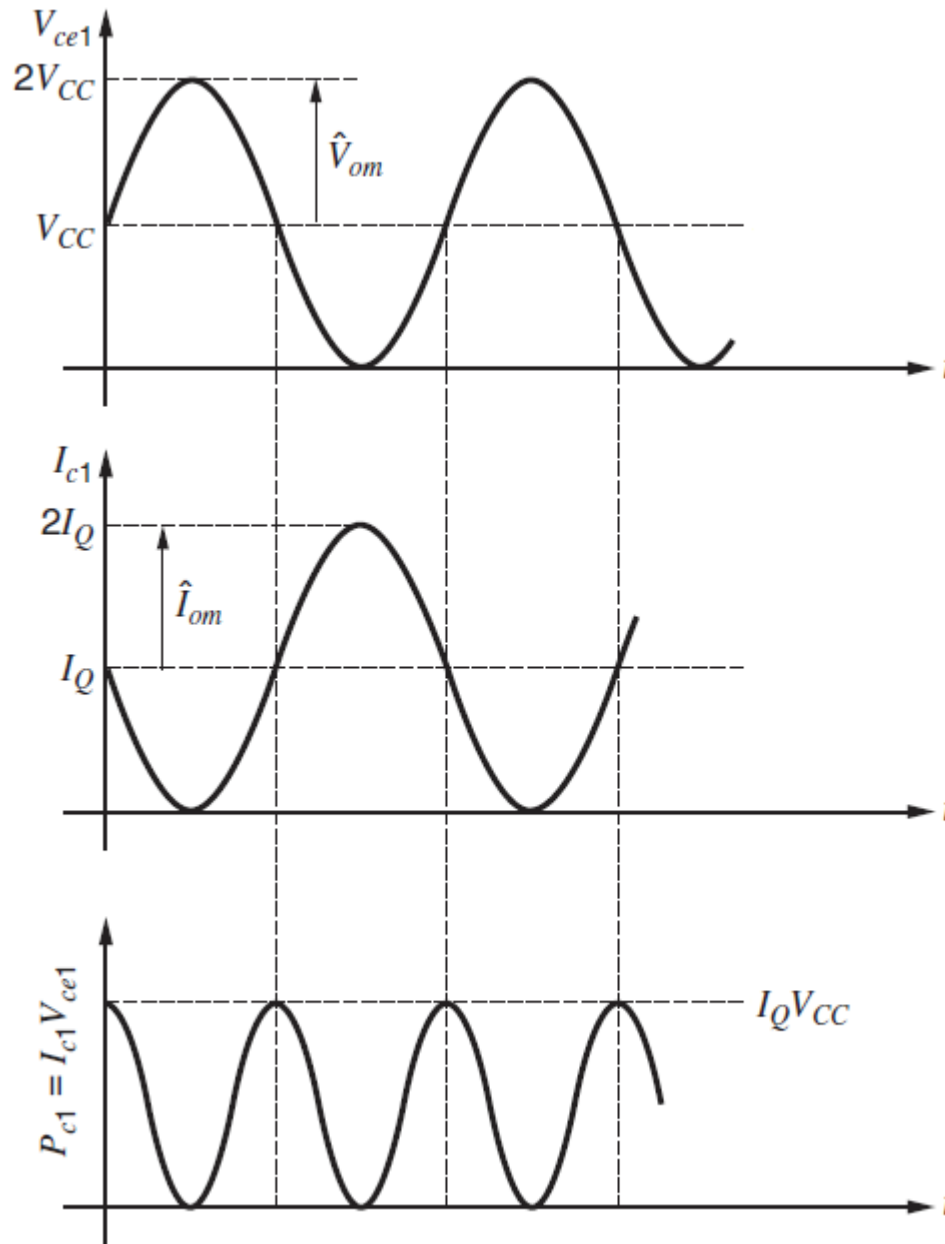
Prenosna karakteristika pojačavača snage sa zajedničkim kolektorom u klasi A



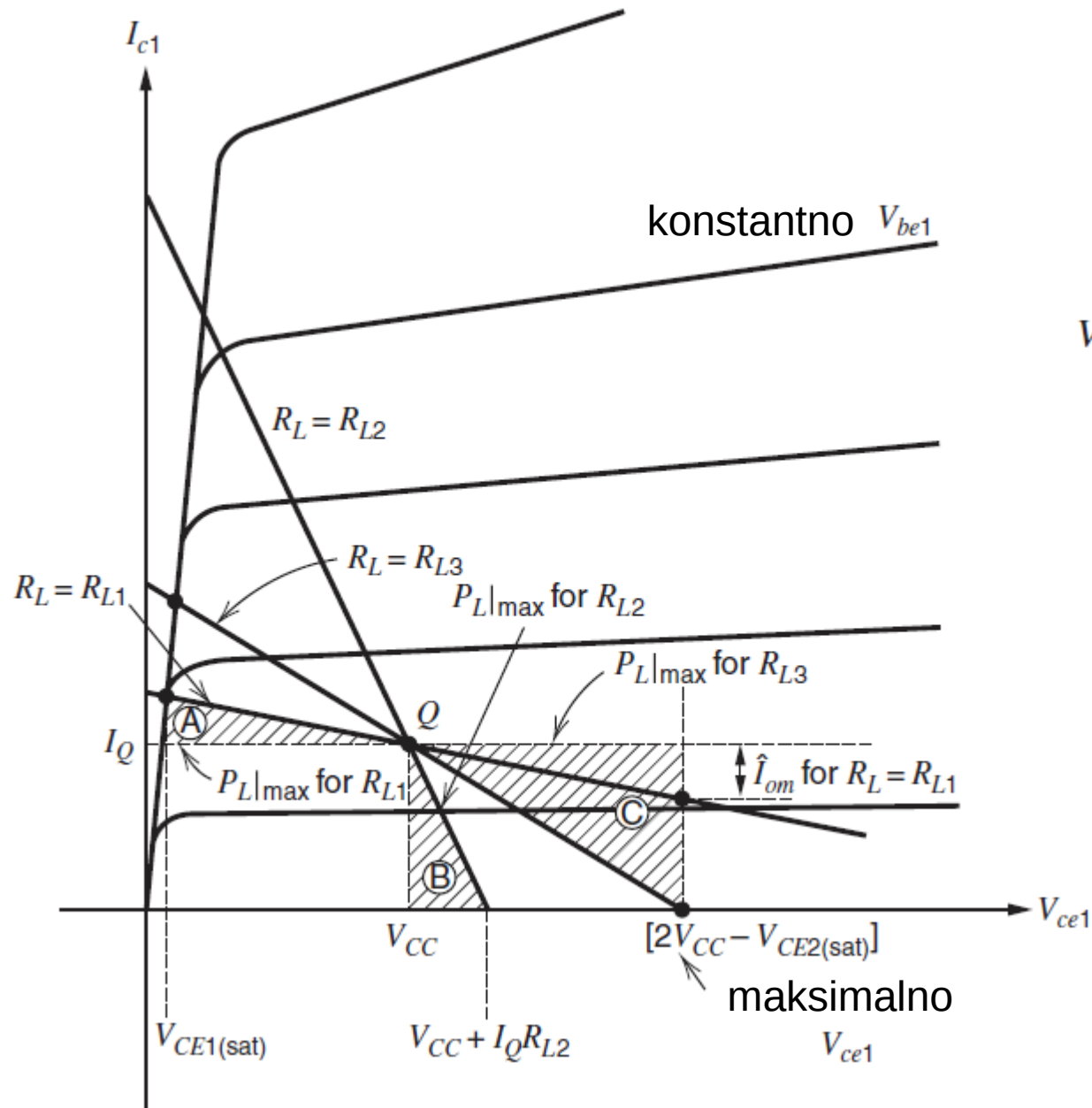
Vremenski dijagrami pojačavača snage sa zajedničkim kolektorom u klasi A



Vremenski dijagrami tranzistora



Izlazne karakteristike za 3 potrošača



$$V_{ce1} = V_{CC} - (I_{c1} - I_Q)R_L$$

maksimalno

Izlazna snaga pojačavača u klasi A

Prosečna snaga $\hat{V}_o$ Amplituda izlaznog sinusoidalnog napona.

$$P_L = \frac{1}{2} \hat{V}_o \hat{I}_o$$

$\hat{I}_o$ Amplituda izlazne sinusoidalne struje.

Maks. snaga $\hat{V}_{om}$ Maksimalna vrednost $\hat{V}_o$ pre odsecanja.

$$P_L|_{\max} = \frac{1}{2} \hat{V}_{om} \hat{I}_{om}$$

$\hat{I}_{om}$ Maksimalna vrednost $\hat{I}_o$ pre odsecanja.

Potrošač

$$\hat{V}_{om} = V_{CC} - V_{CE(\text{sat})}$$

R_{L1}

$$\hat{I}_{om} = \hat{V}_{om} / R_{L1}$$

Potrošač

$$\hat{V}_{om} = I_Q R_{L2}$$

R_{L2}

$$\hat{I}_{om} = I_Q$$

Potrošač

$$\hat{V}_{om} = [V_{CC} - V_{CE(\text{sat})}]$$

R_{L3}

$$\hat{I}_{om} = I_Q$$

$$R_{L3} = \frac{V_{CC} - V_{CE(\text{sat})}}{I_Q}$$

Efikasnost pojačavača u klasi A

Prosečna snaga izvora za napajanje

$$P_{\text{supply}} = 2V_{CC}I_Q$$

Efikasnost pojačavača

$$\eta_C = \frac{P_L}{P_{\text{supply}}}$$

Najveća snaga na potrošaču je za potrošač

$$R_L = R_{L3}$$

Najveća snaga na potrošaču

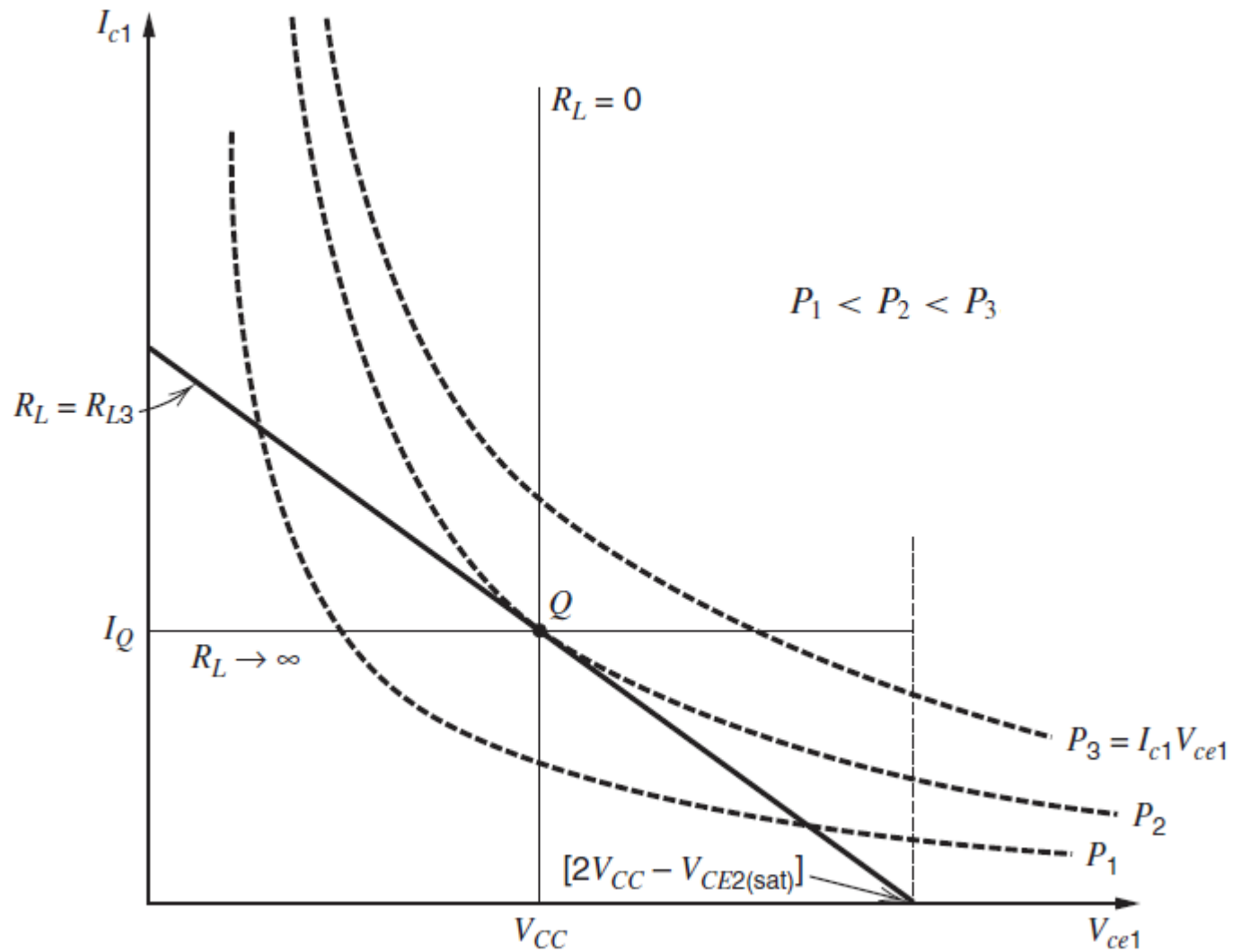
$$P_L|_{\text{max}} = \frac{1}{2}\hat{V}_{om}\hat{I}_{om} = \frac{1}{2}[V_{CC} - V_{CE(\text{sat})}]I_Q$$

Maksimalna efikasnost pojačavača je 25%

$$\eta_{\text{max}} = \frac{1}{4} \left(1 - \frac{V_{CE(\text{sat})}}{V_{CC}} \right)$$

$$V_{CE(\text{sat})} \ll V_{CC}$$

Hiperbole snage tranzistora



Trenutna disipacija tranzistora

Trenutna disipacija snage na tranzistoru $P_{c1} = V_{ce1} I_{c1}$

$$P_{c1} = V_{CC}(1 + \sin \omega t) I_Q (1 - \sin \omega t) = \frac{V_{CC} I_Q}{2} (1 + \cos 2\omega t)$$

Hiperbola snage tranzistora

$$I_{c1} = \frac{P_2}{V_{ce1}}$$

Nagib hiperbole snage

$$\frac{dI_{c1}}{dV_{ce1}} = -\frac{P_2}{V_{ce1}^2}$$

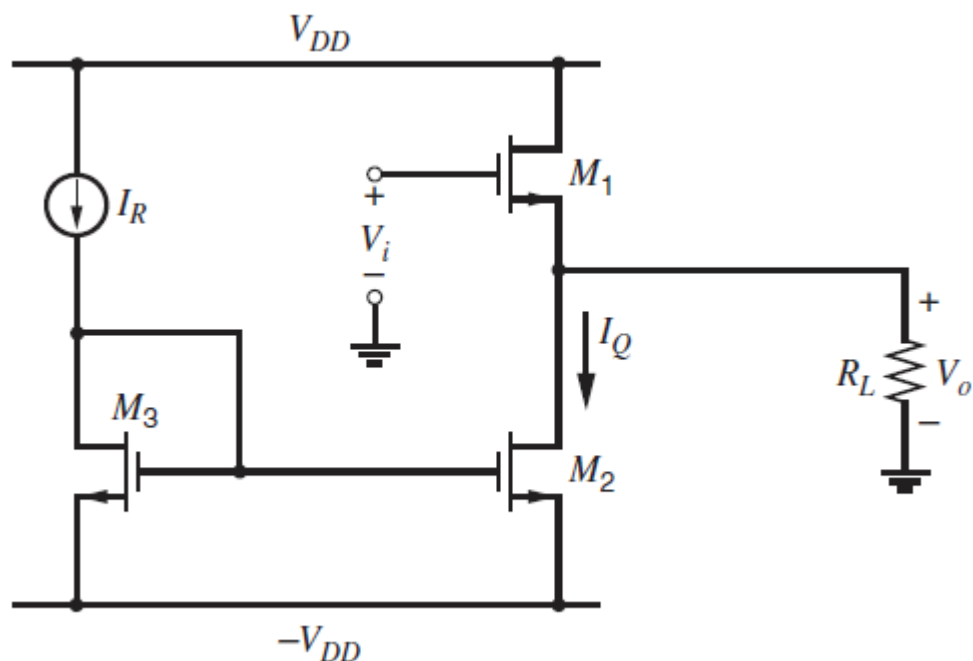
$$\frac{dI_{c1}}{dV_{ce1}} = -\frac{I_{c1}}{V_{ce1}}$$

$$\left. \frac{dI_{c1}}{dV_{ce1}} \right|_Q = -\frac{I_Q}{V_{CC}}$$

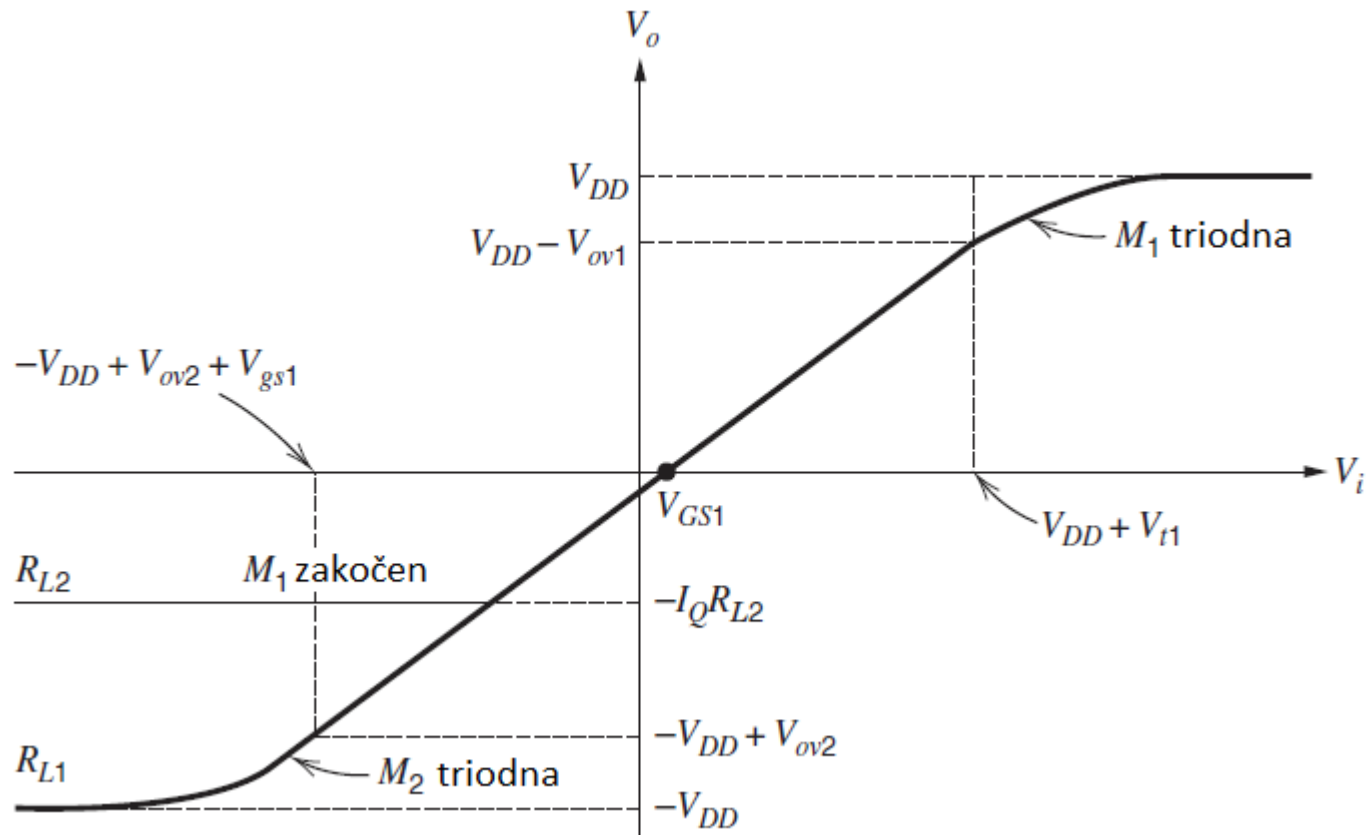
$$R_L = R_{L3}$$

$$-\frac{1}{R_{L3}} \simeq -\frac{I_Q}{V_{CC}}$$

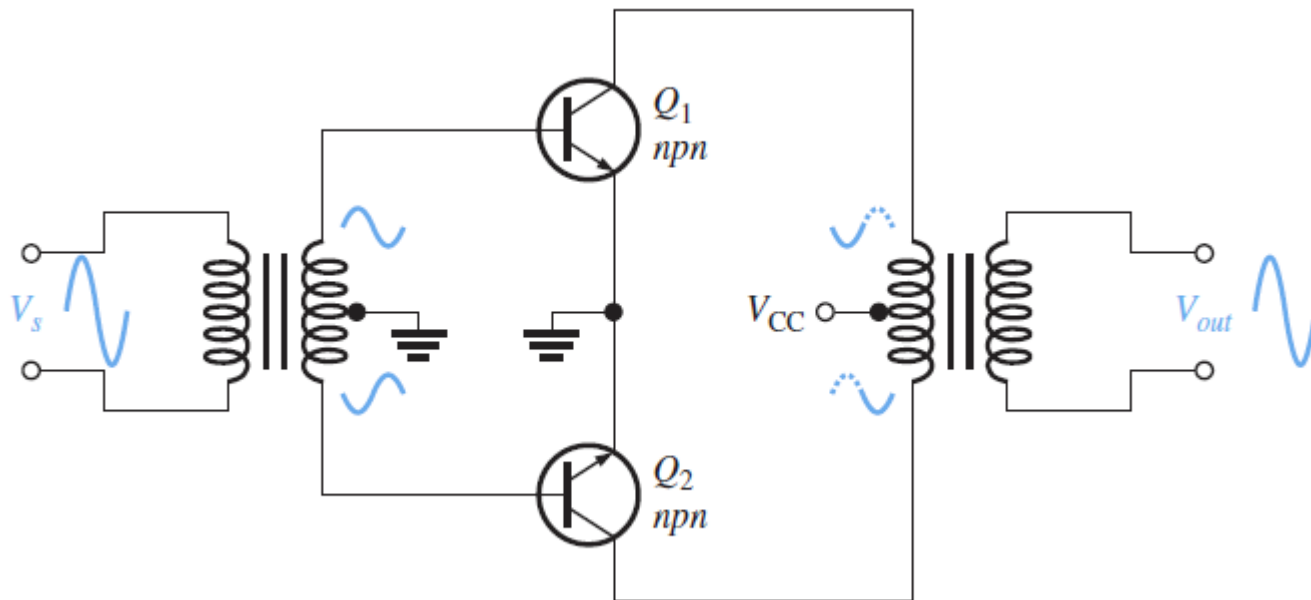
Pojačavač snage sa zajedničkim drejnom u klasi A



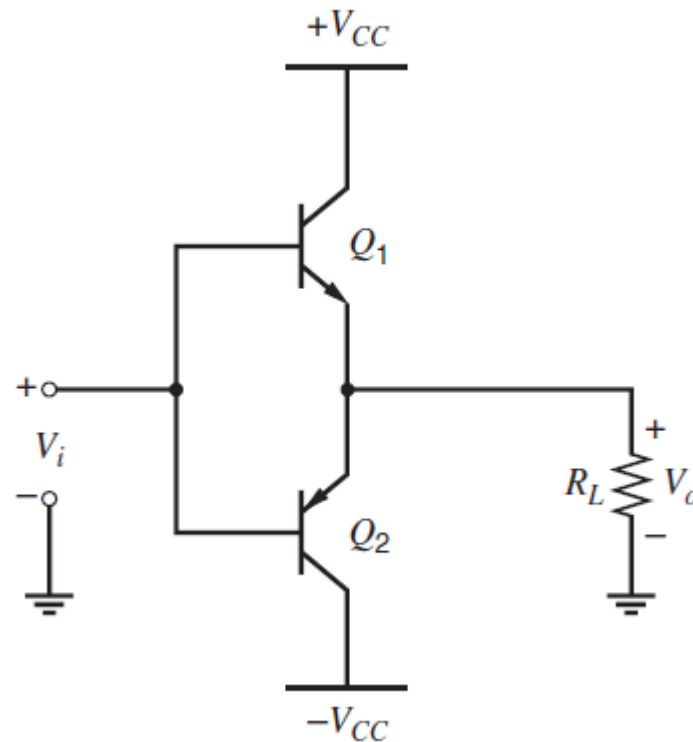
Prenosna karakteristika pojačavača snage sa zajedničkim drejnom u klasi A



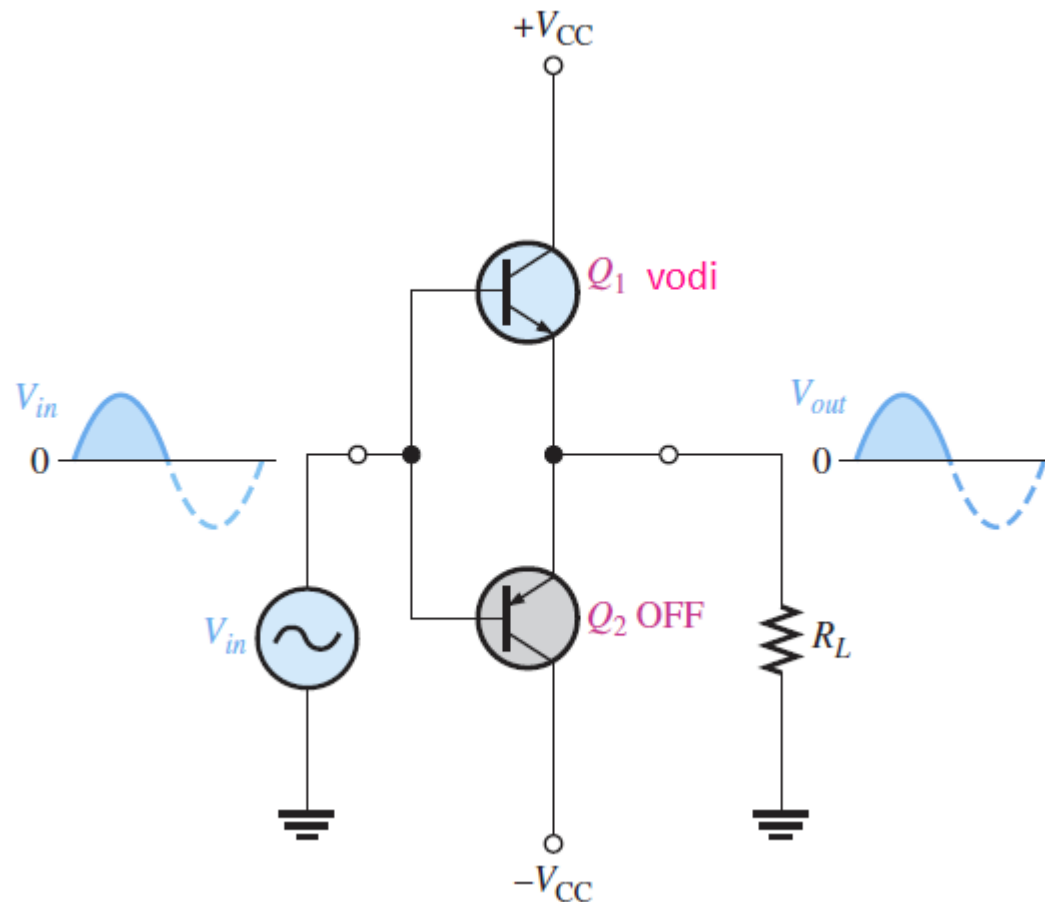
Push-pull pojačavač snage sa transformatorskom spregom u klasi B (vodi ili Q_1 ili Q_2)



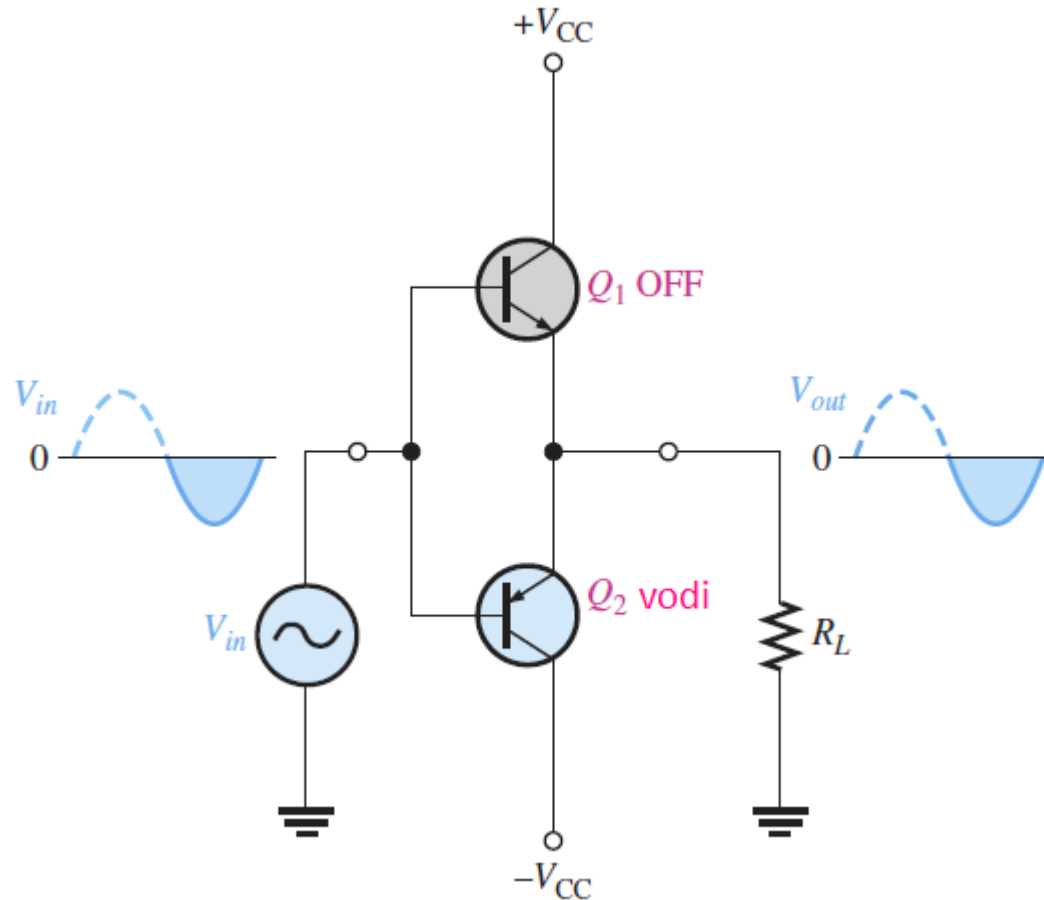
Push-pull pojačavač snage u klasi B (vodi ili Q_1 ili Q_2)



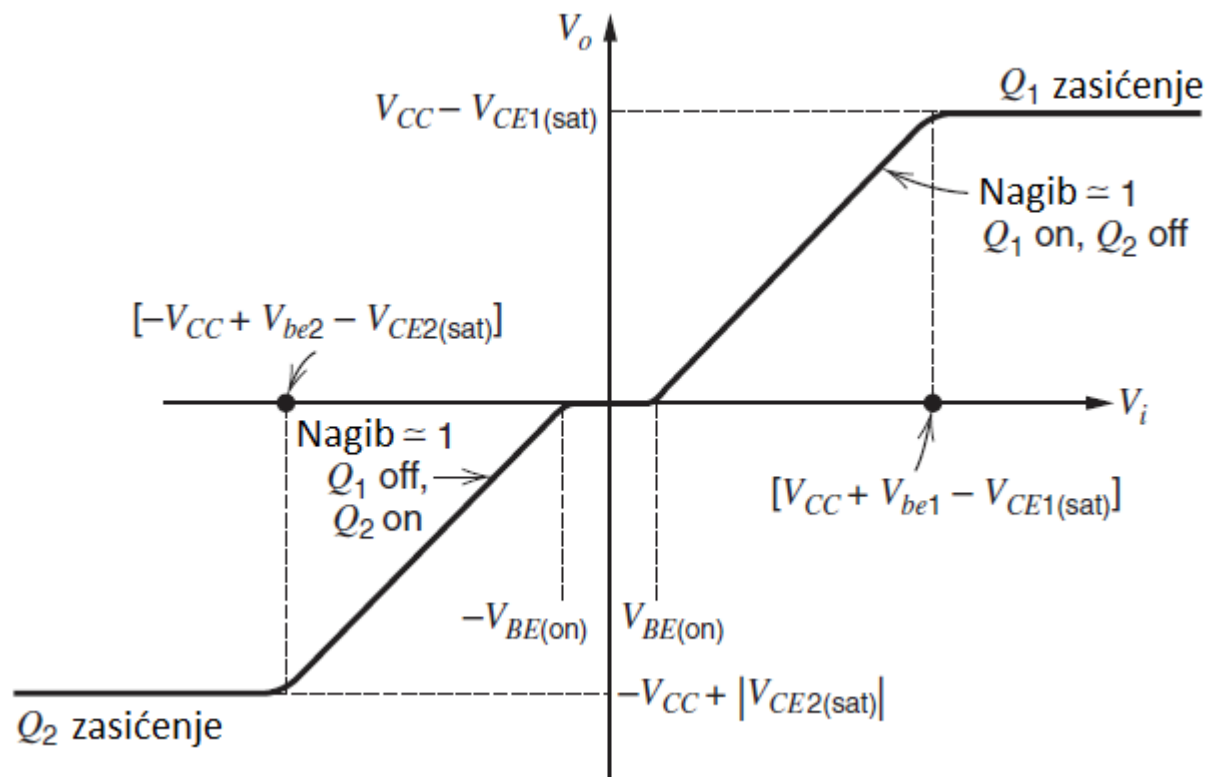
Push-pull pojačavač snage u klasi B (vodi Q_1 u toku $\pi \equiv 180^\circ$)



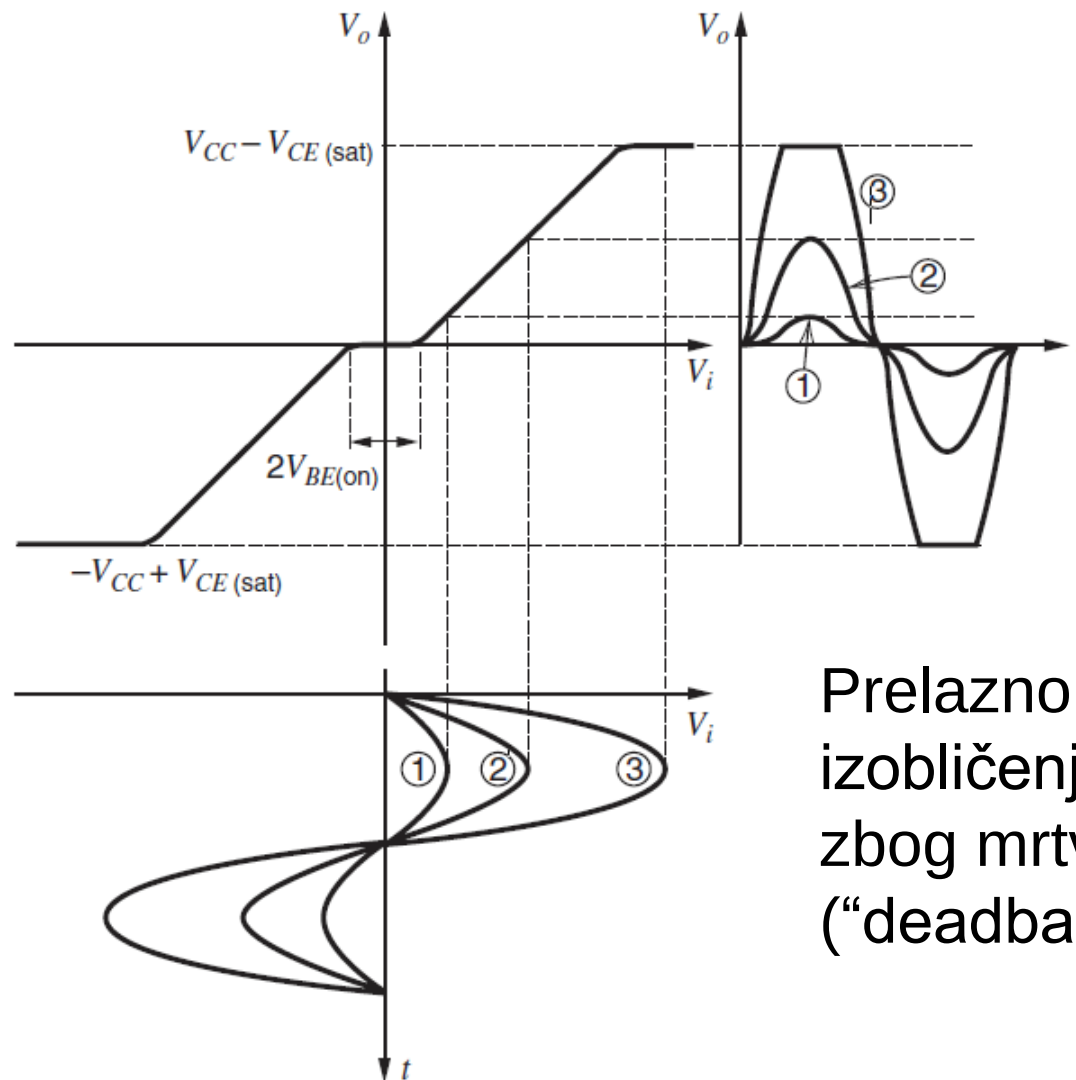
Push-pull pojačavač snage u klasi B (vodi Q_2 u toku $\pi \equiv 180^\circ$)



Prenosna karakteristika push-pull pojačavača snage u klasi B

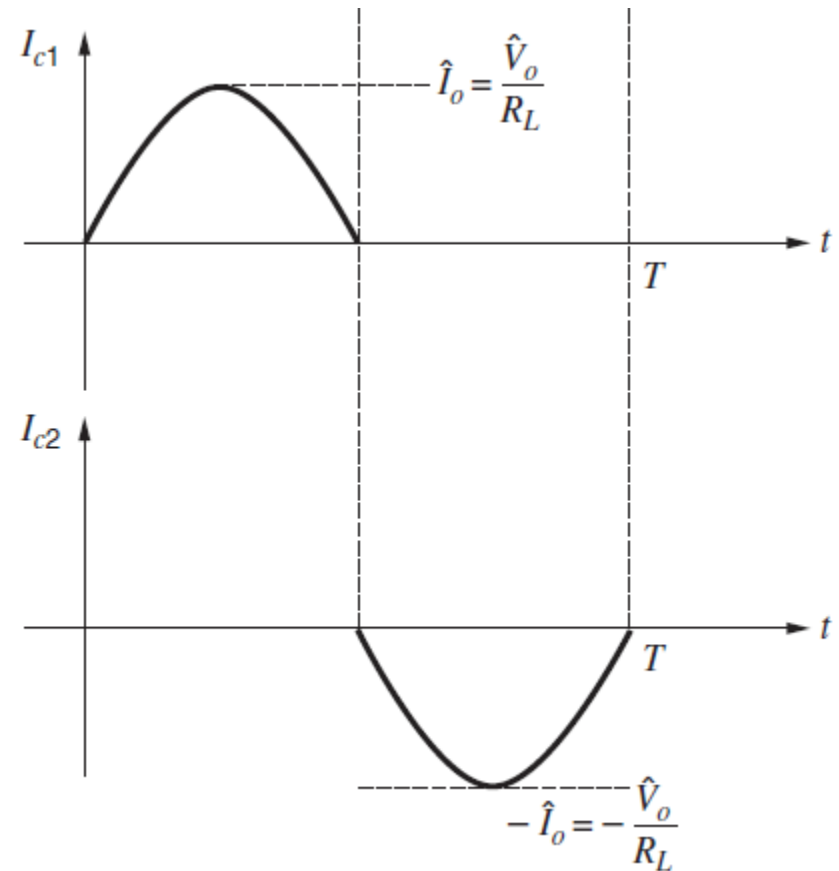
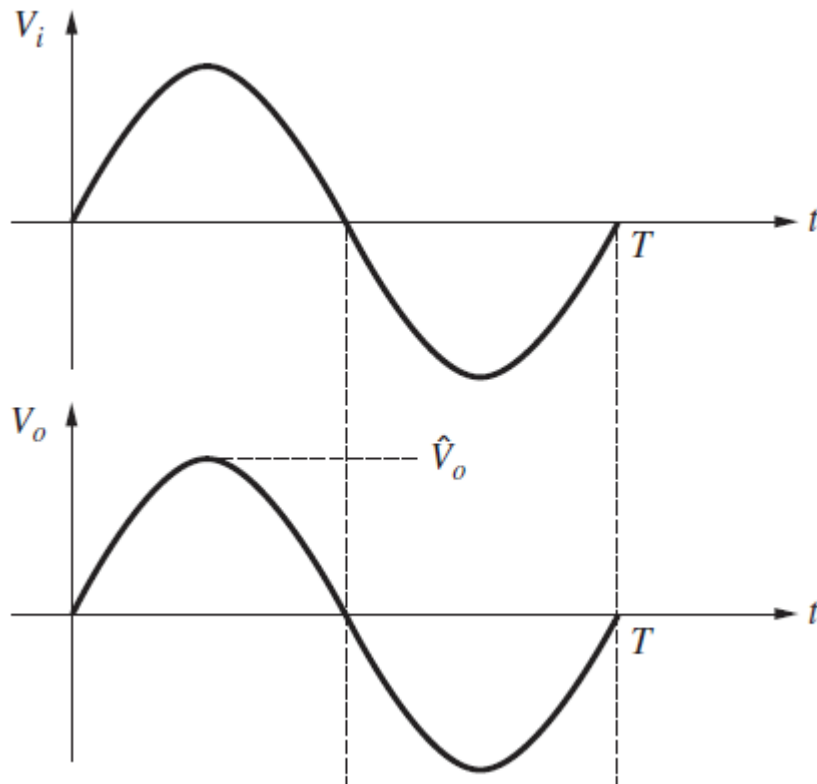


Vremenski dijagrami push-pull pojačavača snage u klasi B

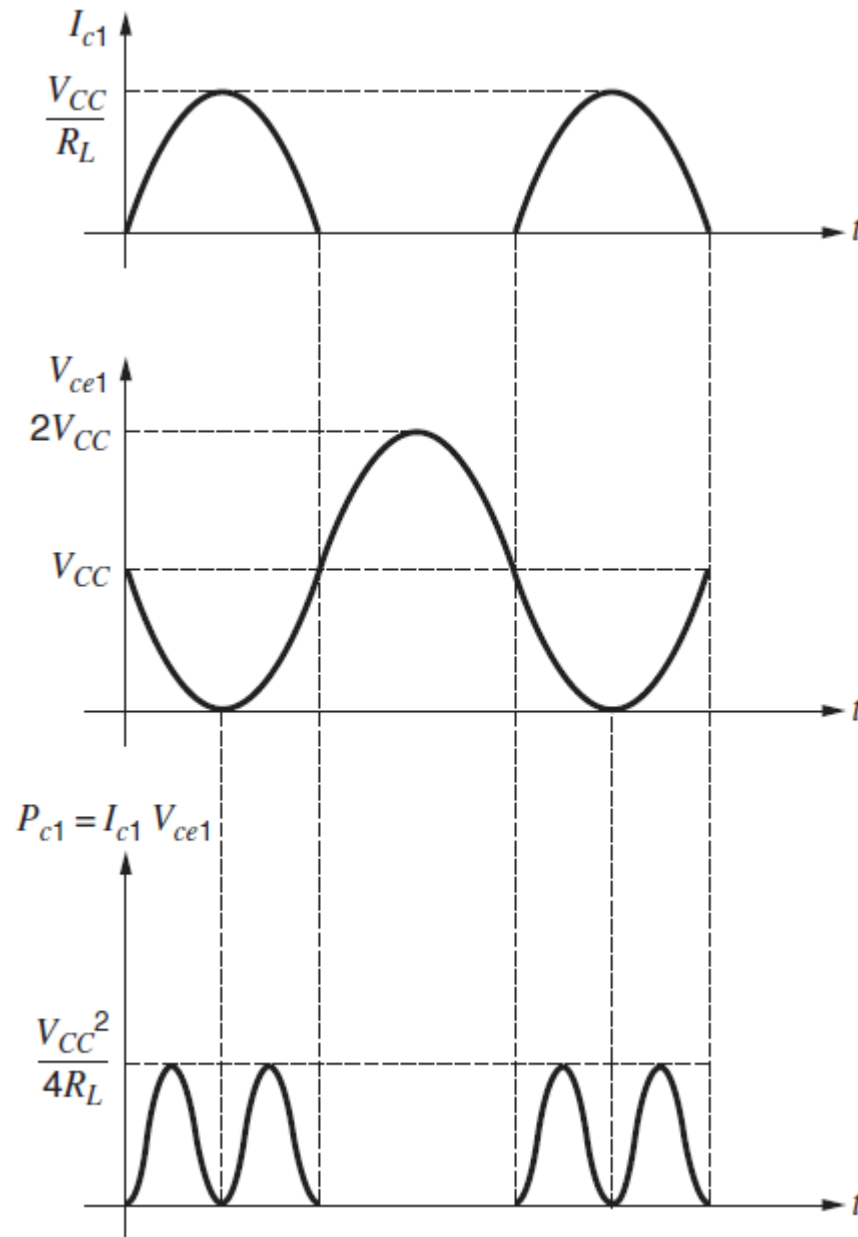


Prelazno (“crossover”) izobličenje nastaje zbog mrtve zone (“deadband”) od $2V_{BE(on)}$.

Vremenski dijagrami push-pull pojačavača snage u klasi B sa zanemarenom mrtvom zonom



Vremenski dijagrami tranzistora



Izlazna snaga pojačavača u klasi B

Prosečna snaga $\hat{V}_o$ Amplituda izlaznog sinusiodalnog napona.

$$P_L = \frac{1}{2} \hat{V}_o \hat{I}_o$$

$\hat{I}_o$ Amplituda izlazne sinusiodalne struje.

$$P_L = \frac{1}{2} \frac{\hat{V}_o^2}{R_L}$$

Maks. snaga $\hat{V}_{om}$ Maksimalna vrednost $\hat{V}_o$ pre odsecanja.

$$P_{L|_{\max}} = \frac{1}{2} \hat{V}_{om} \hat{I}_{om}$$

$\hat{I}_{om}$ Maksimalna vrednost $\hat{I}_o$ pre odsecanja.

$$\hat{V}_{om} = V_{CC} - V_{CE(\text{sat})}$$

$$P_{L|_{\max}} = \frac{1}{2} \frac{[V_{CC} - V_{CE(\text{sat})}]^2}{R_L}$$

Efikasnost pojačavača u klasi B

Prosečna struja izvora za napajanje

$$I_{\text{supply}} = \frac{1}{T} \int_0^T I_{c1}(t) dt = \frac{1}{T} \int_0^{T/2} \frac{\hat{V}_o}{R_L} \sin\left(\frac{2\pi t}{T}\right) dt = \frac{1}{\pi} \frac{\hat{V}_o}{R_L} = \frac{1}{\pi} \hat{I}_o$$

Prosečna snaga izvora za napajanje

$$P_{\text{supply}} = 2V_{CC} I_{\text{supply}} = \frac{2}{\pi} \frac{V_{CC}}{R_L} \hat{V}_o$$

Efikasnost pojačavača za $P_L = \frac{1}{2} \frac{\hat{V}_o^2}{R_L}$

$$\eta_C = \frac{P_L}{P_{\text{supply}}} = \frac{\pi}{4} \frac{\hat{V}_o}{V_{CC}}$$

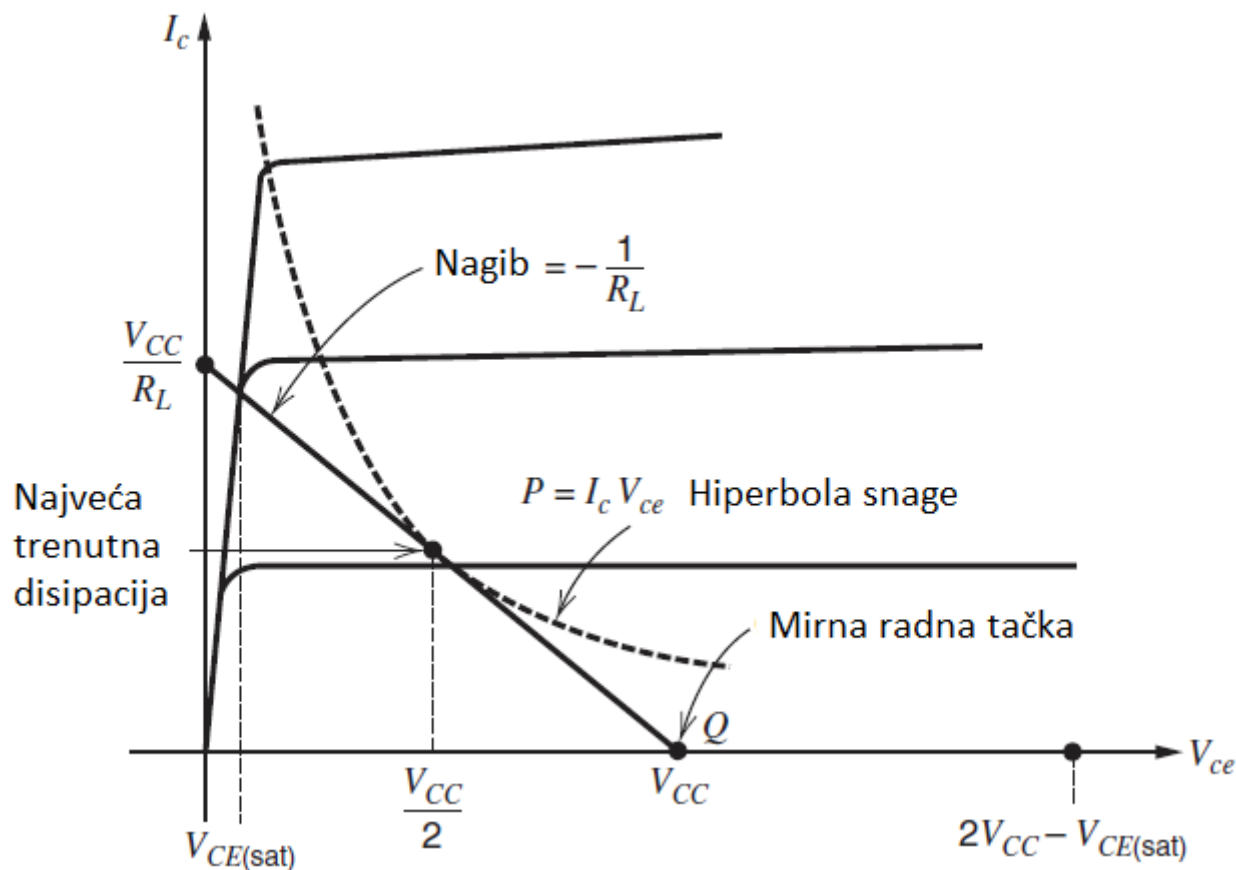
Najveća snaga na potrošaču

$$P_L|_{\text{max}} = \frac{1}{2} \frac{[V_{CC} - V_{CE(\text{sat})}]^2}{R_L}$$

Maksimalna efikasnost pojačavača je 78.5% $\eta_{\text{max}} = \frac{\pi}{4} \left(\frac{V_{CC} - V_{CE(\text{sat})}}{V_{CC}} \right)$

$$V_{CE(\text{sat})} \ll V_{CC}$$

Izlazne karakteristike i hiperbole snage tranzistora



Trenutna disipacija tranzistora

Trenutna disipacija snage na tranzistoru

$$P_c = V_{ce} I_c$$

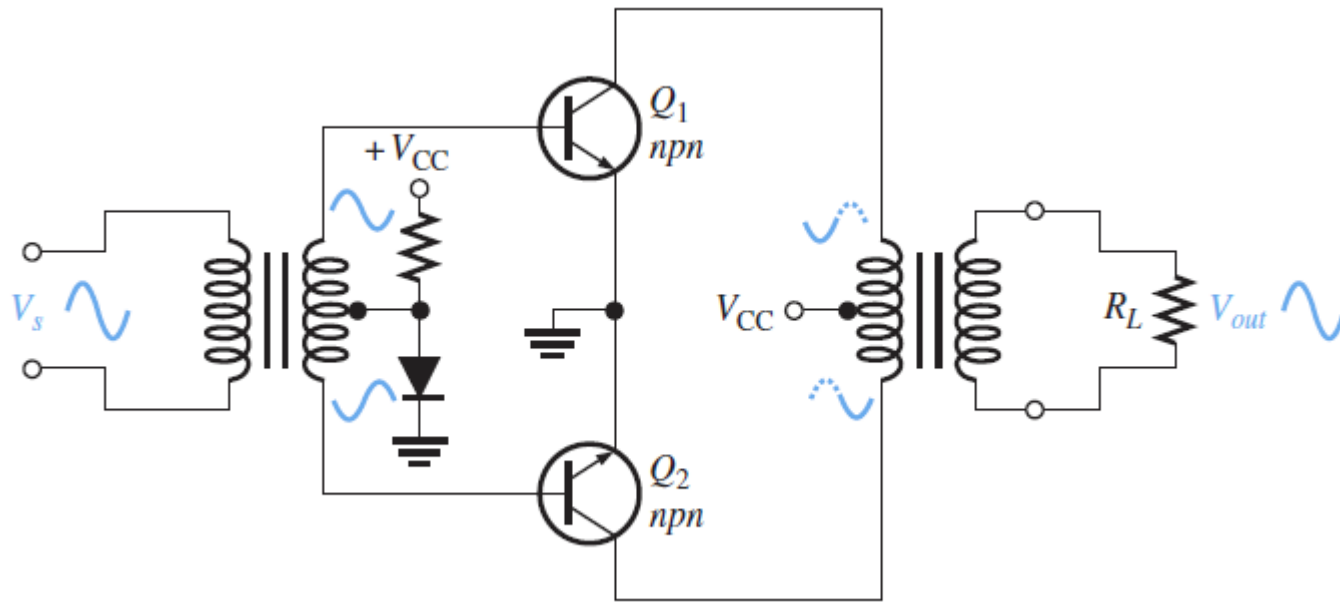
$$V_{ce} = V_{CC} - I_c R_L$$

$$P_c = I_c (V_{CC} - I_c R_L) = I_c V_{CC} - I_c^2 R_L$$

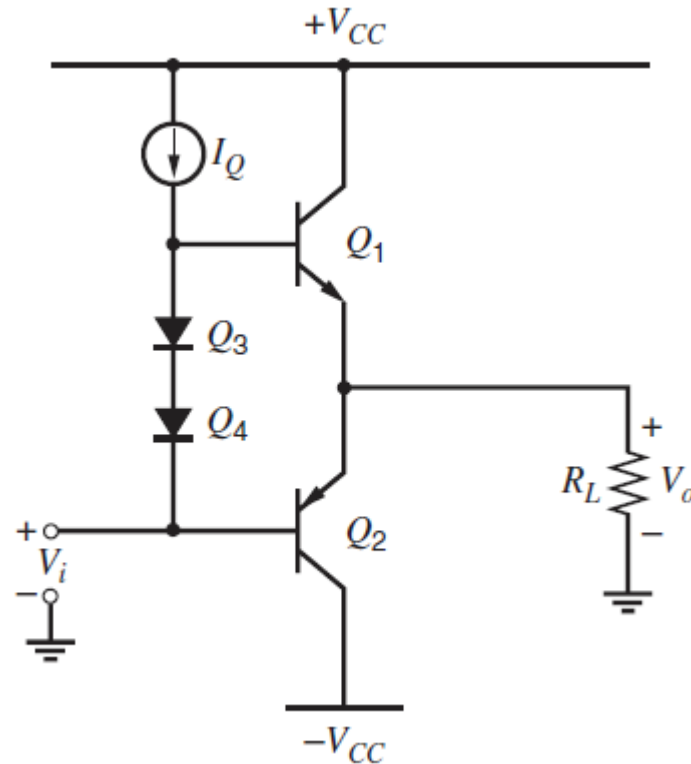
$$\frac{dP_c}{dI_c} = V_{CC} - 2R_L I_c = 0$$

Najveća trenutna disipacija snage je za $I_c = \frac{V_{CC}}{2R_L}$ što je na polovini nagnutog dela radne prave.

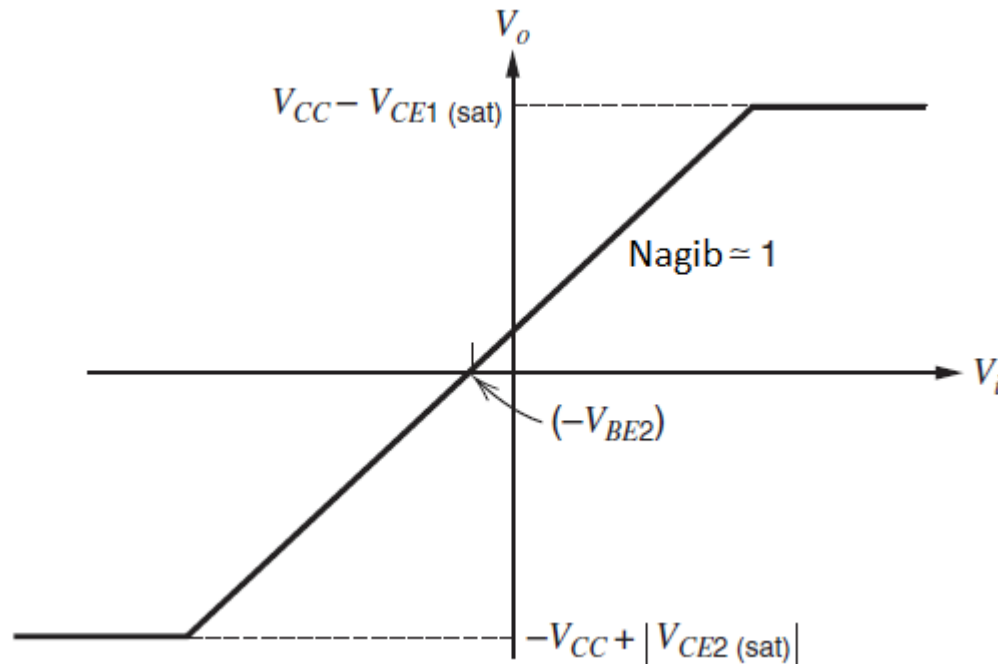
Push-pull pojačavač snage sa transformatorskom spregom u klasi AB (vodi ili Q_1 ili Q_2 sa malom zonom preklapanja kada vode oba)



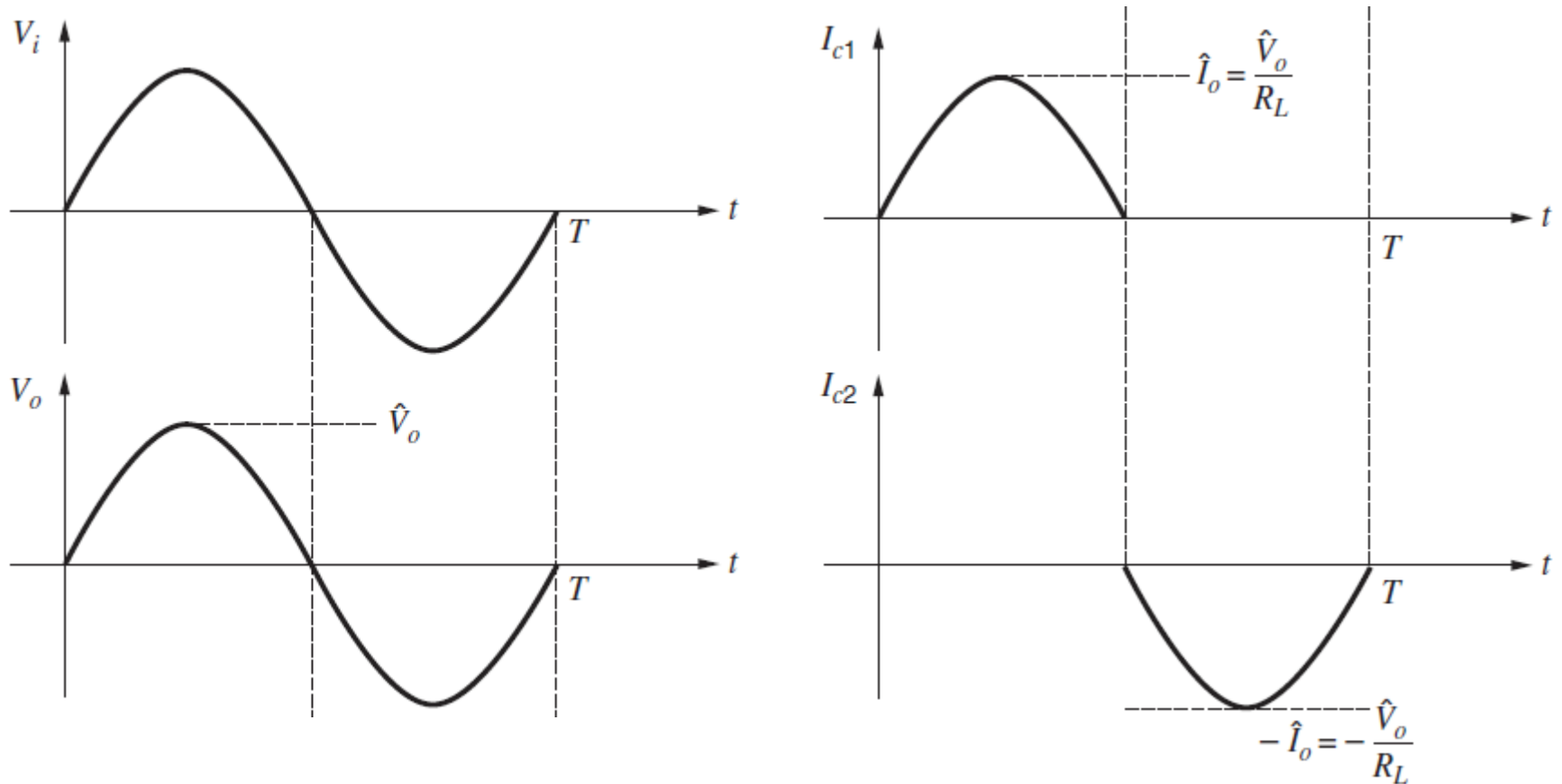
Push-pull pojačavač snage u klasi AB (vodi ili Q_1 ili Q_2 sa malom zonom preklapanja kada vode oba)



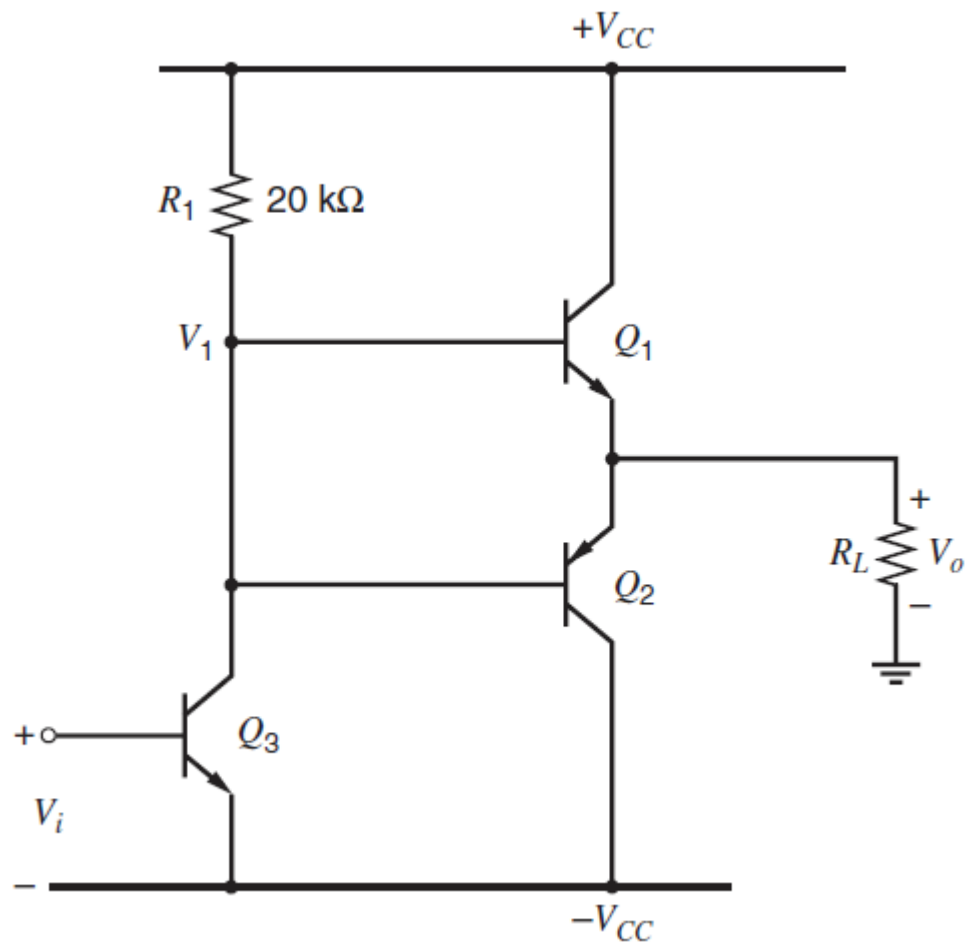
Prenosna karakteristika push-pull pojačavača snage u klasi AB



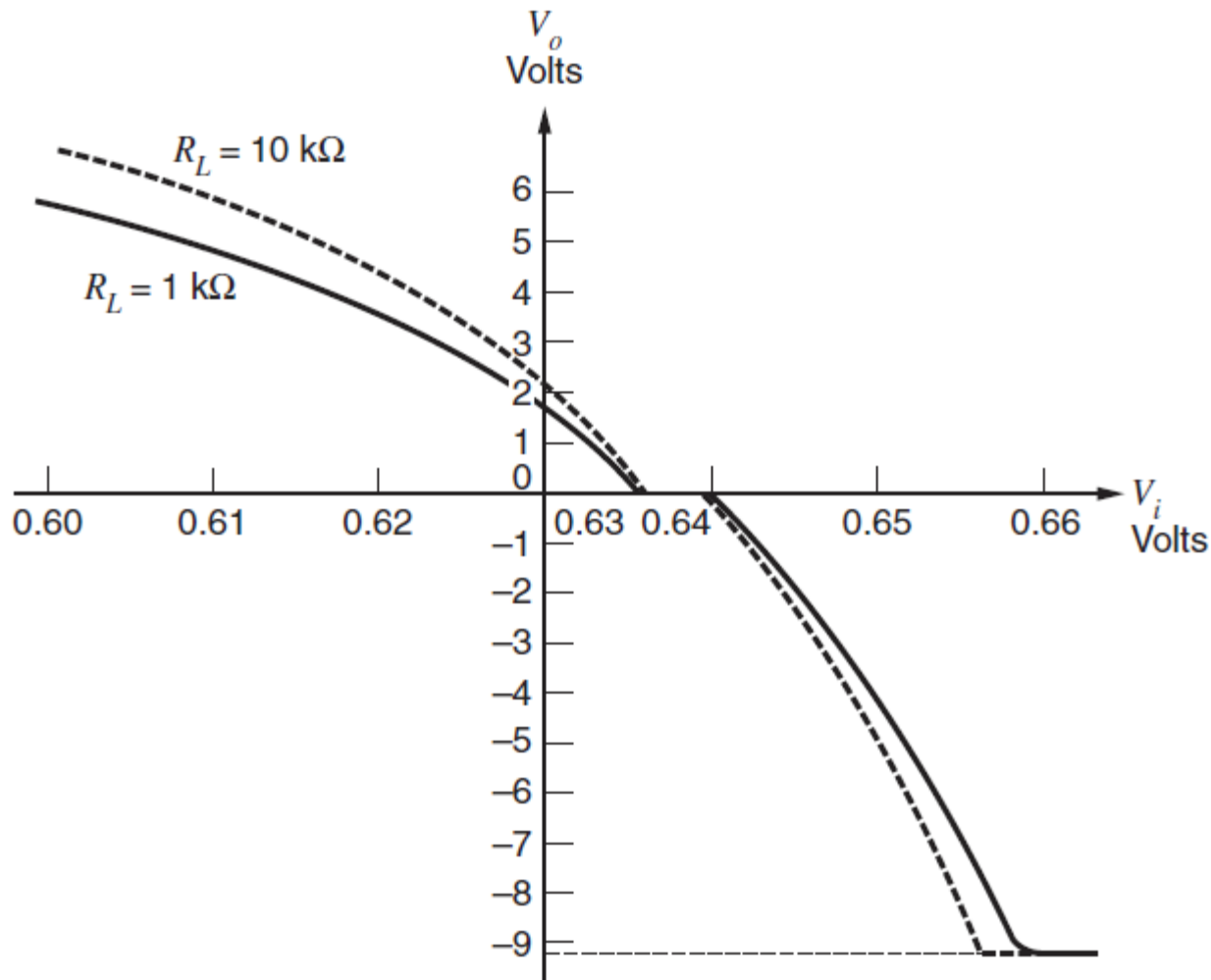
Vremenski dijagrami push-pull pojačavača snage u klasi AB



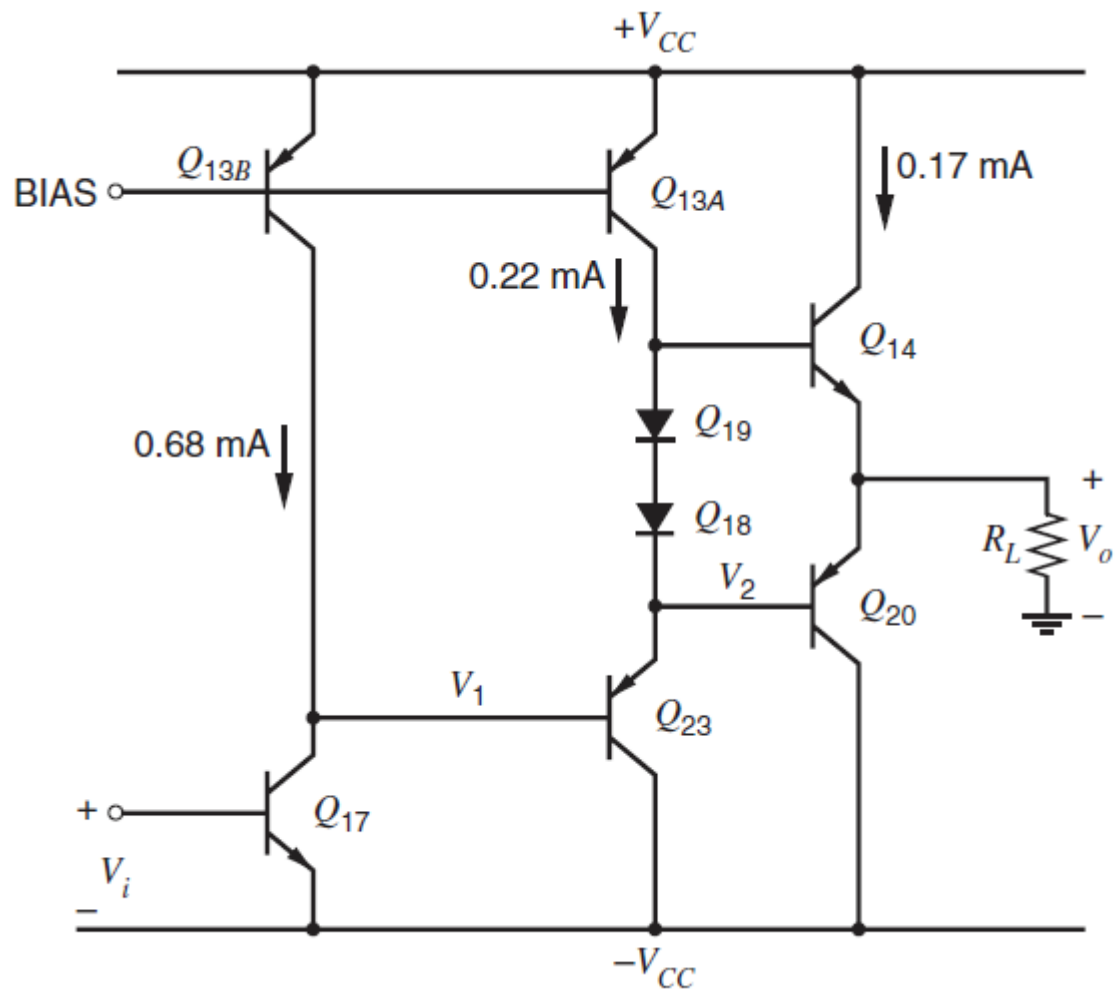
Push-pull pojačavač snage u klasi B sa pretpojačavačem



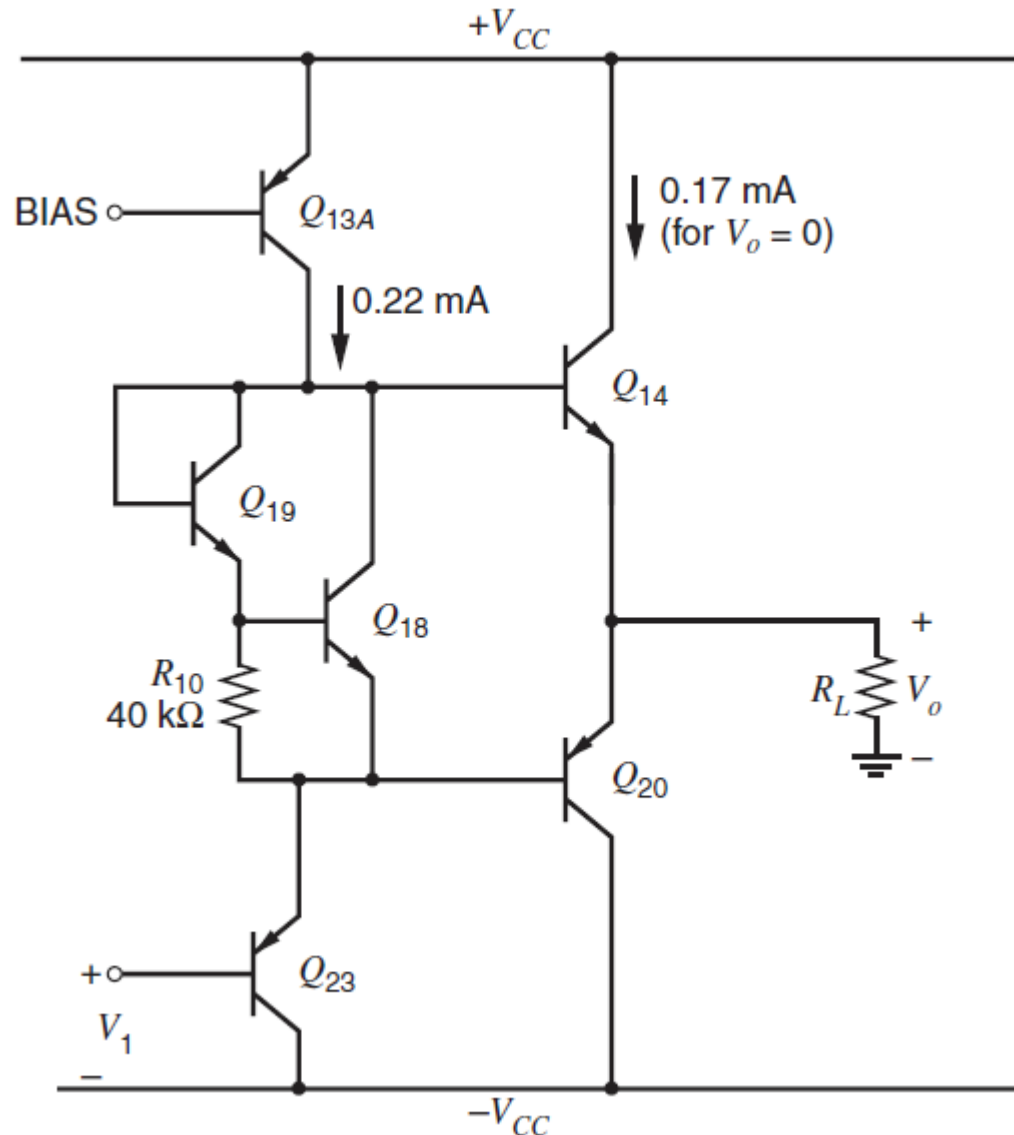
Nelinearna prenosna karakteristika push-pull pojačavača snage u klasi B sa pretpojačavačem



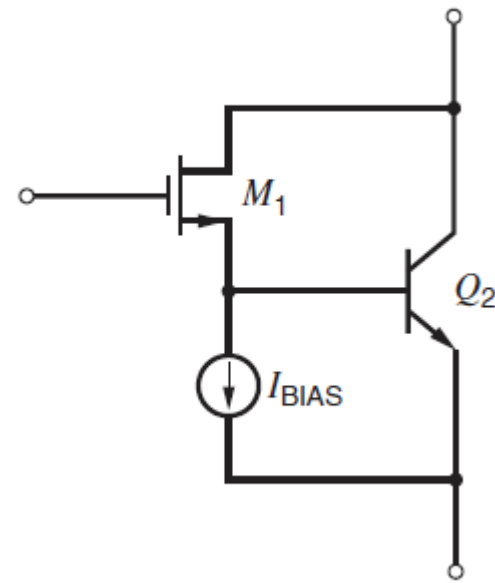
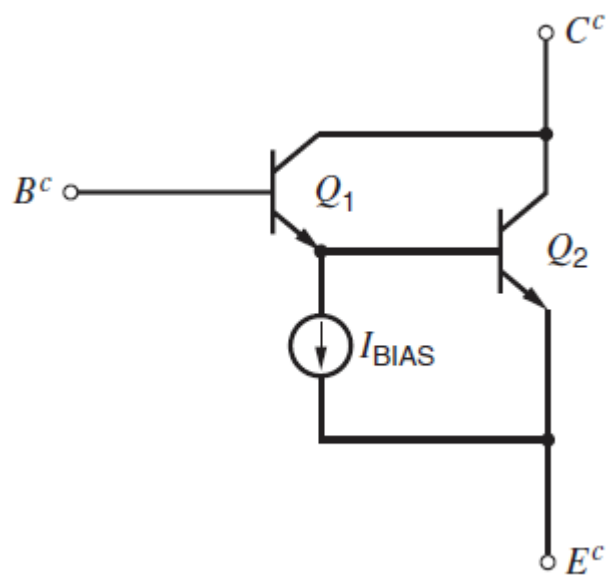
Push-pull pojačavač snage u klasi AB za operacioni pojačavač



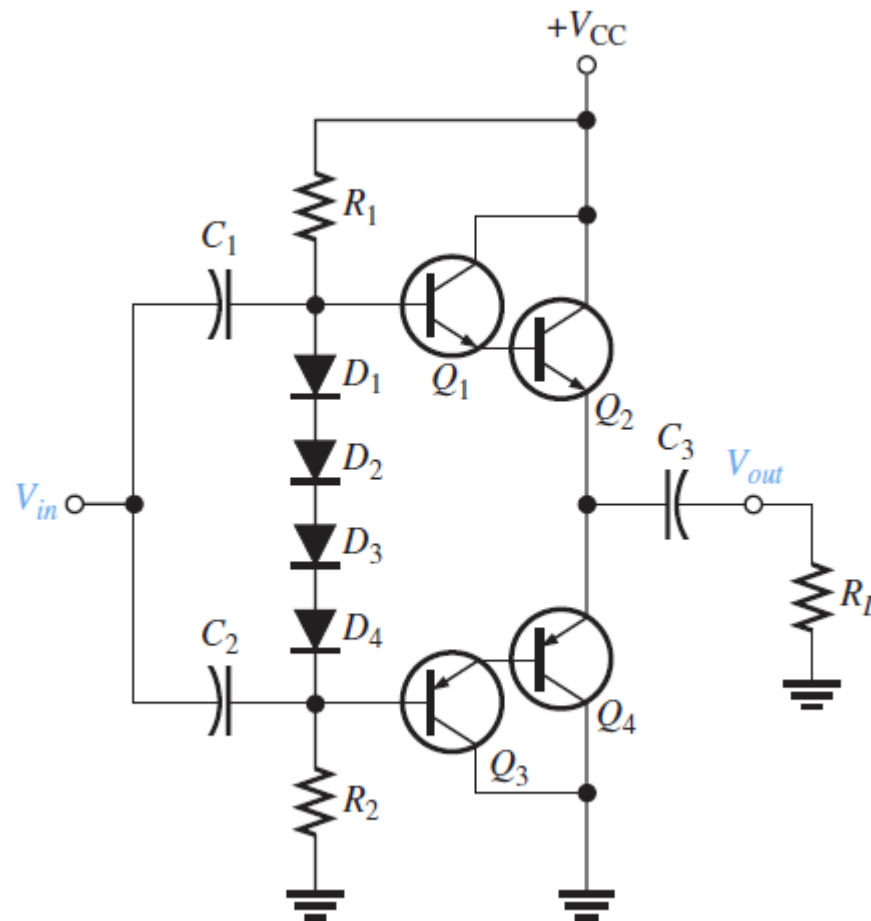
Push-pull pojačavač snage u klasi AB za operacioni pojačavač



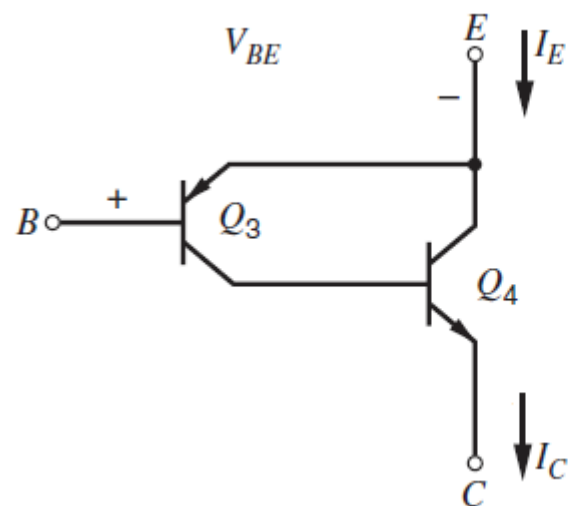
Darlington par umesto jednog izlaznog npn tranzistora



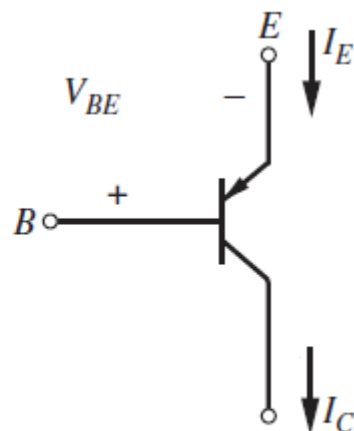
Pojačavač snage u klasi AB sa komplementarnim Darlingtonovima (i jednostrukim napajanjem)



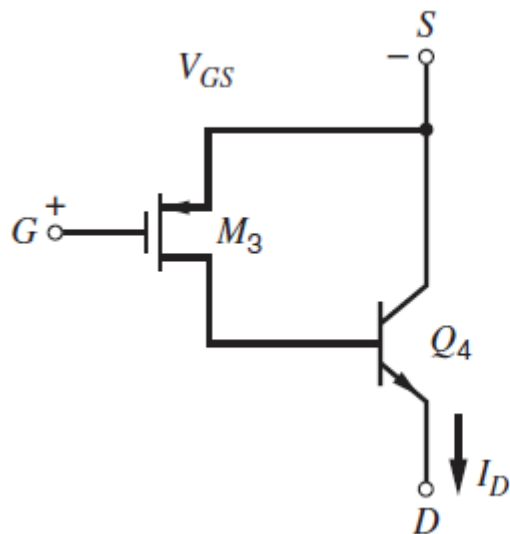
Kvazikomplementarni Darlington par



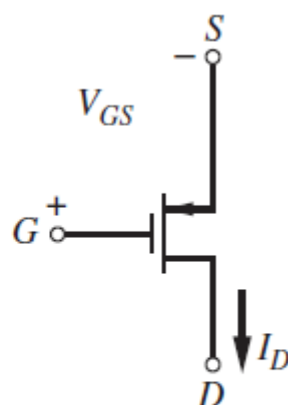
$\equiv$



$$I_C = (\beta_{F4} + 1)I_{C3} = (\beta_{F4} + 1)I_S \exp\left(-\frac{V_{BE}}{V_T}\right)$$

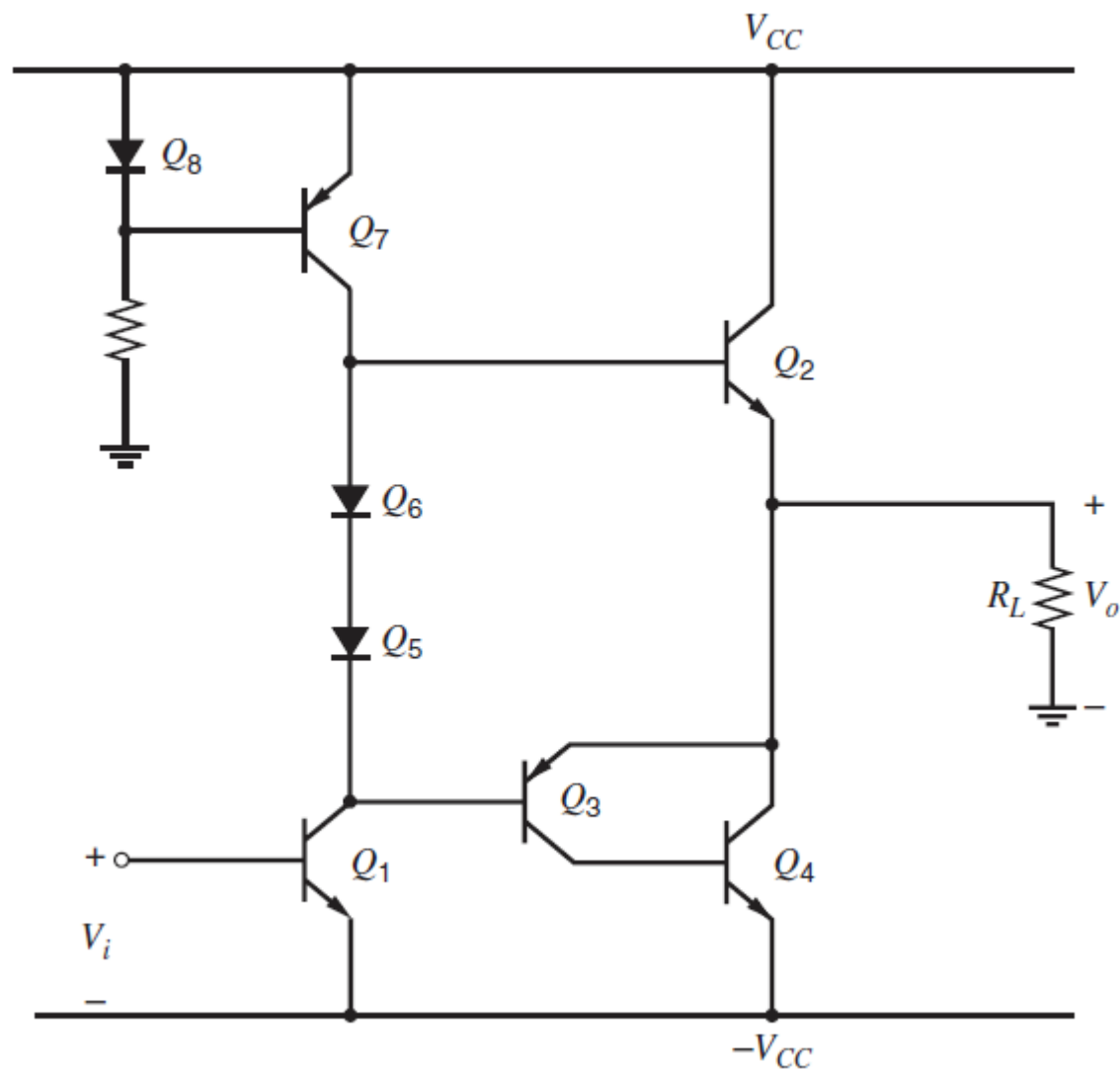


$\equiv$

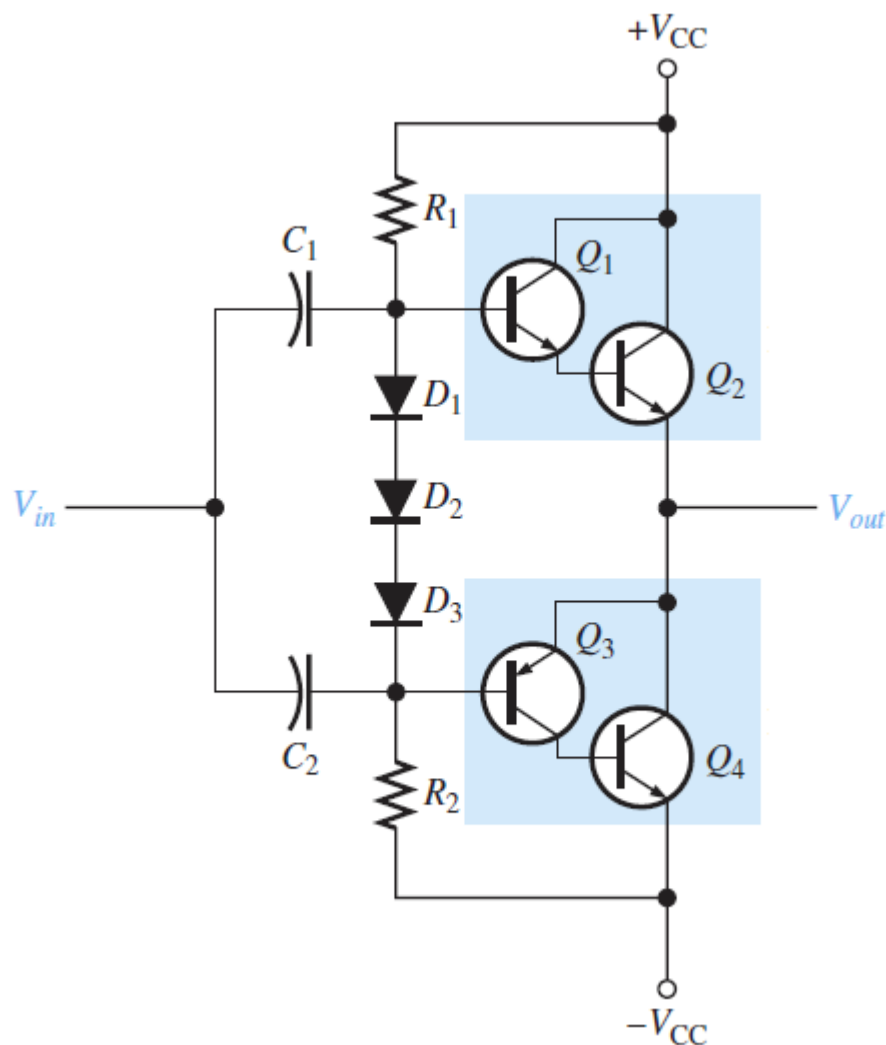


$$I_D = (\beta_{F4} + 1)I_{D3} = (\beta_{F4} + 1)\frac{\mu_n C_{ox}}{2} \left(\frac{W}{L}\right)_3 (V_{GS} - V_t)^2$$

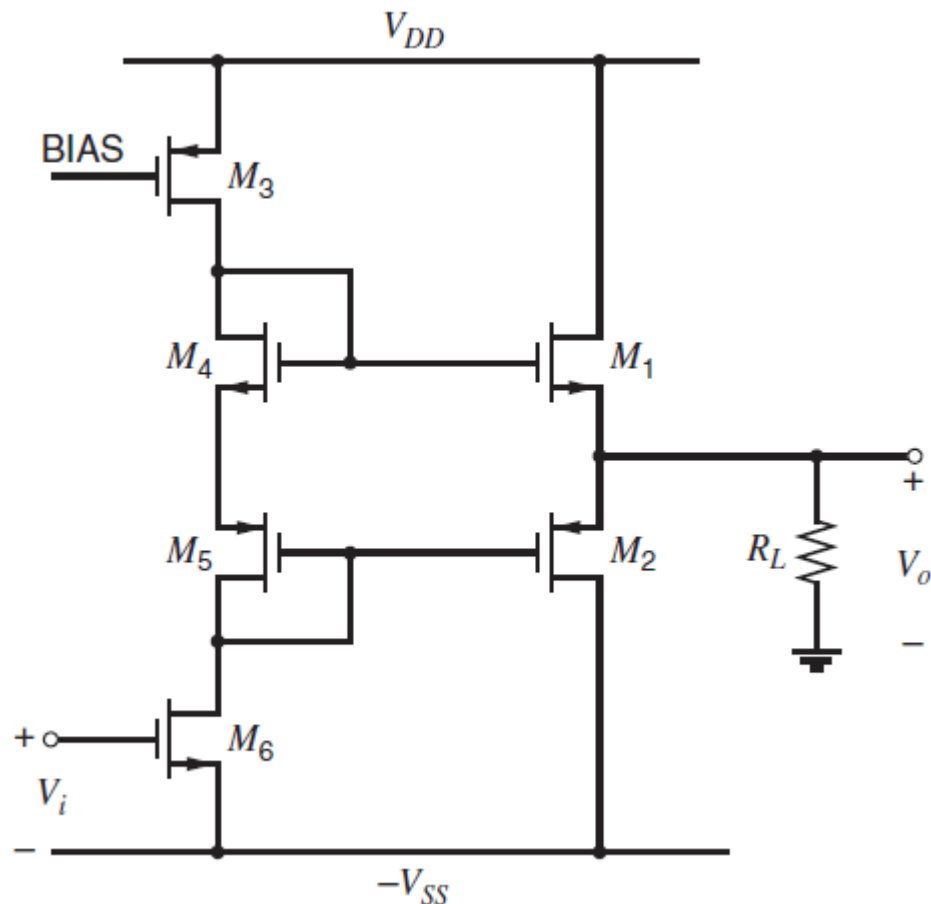
Pojačavač snage u klasi AB sa kvazi-komplementarnim Darlingtonom



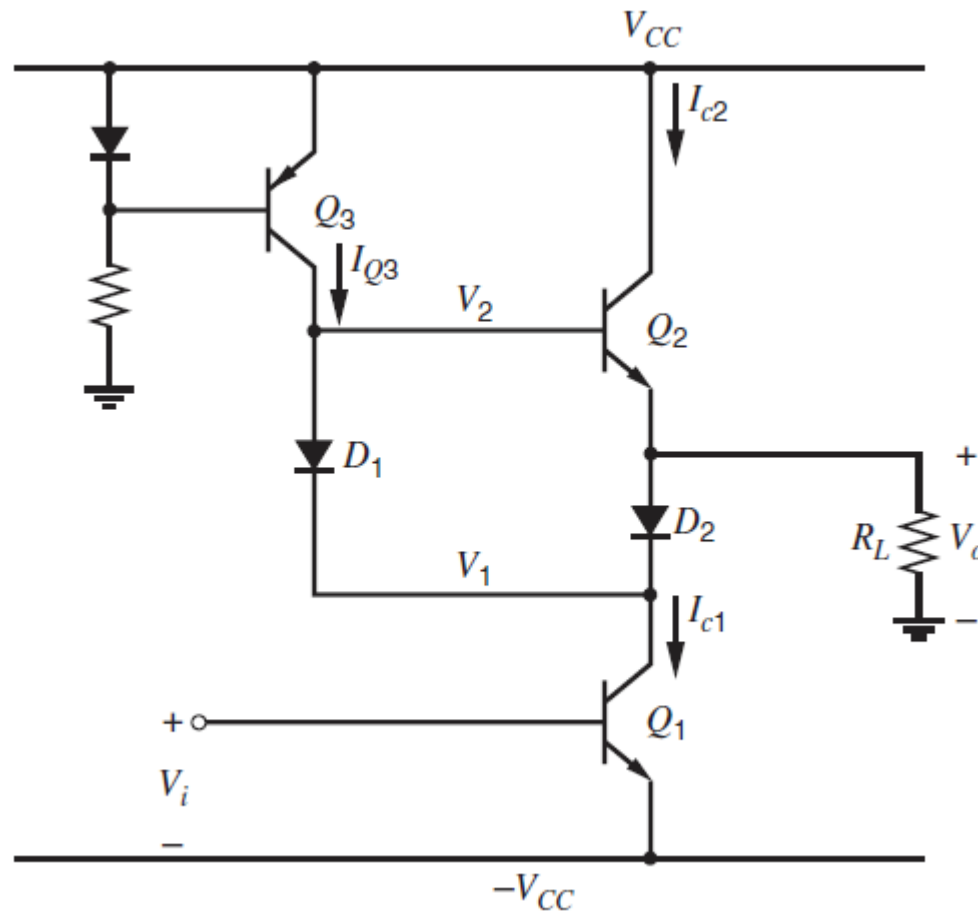
Pojačavač snage u klasi AB sa kvazi-komplementarnim Darlingtonom



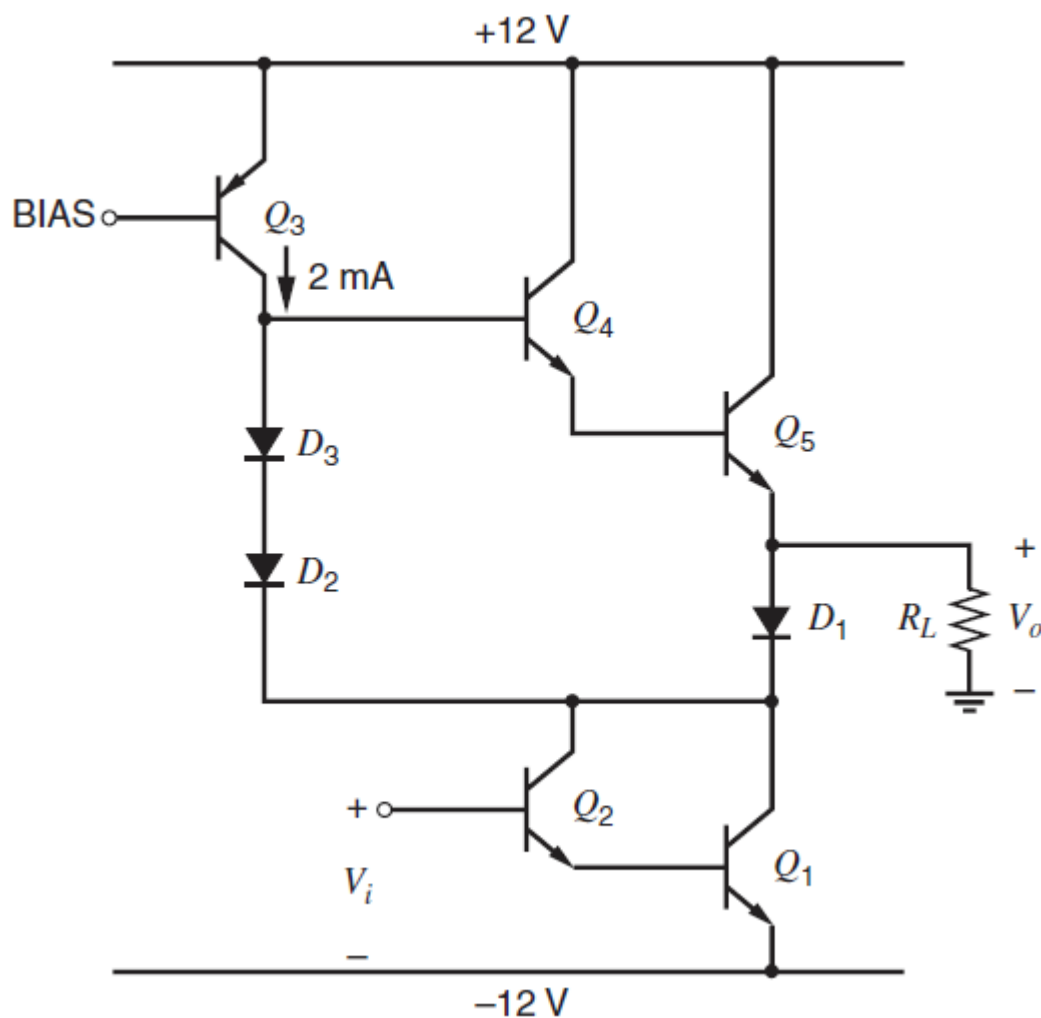
Pojačavač snage sa MOS tranzistorima u klasi AB



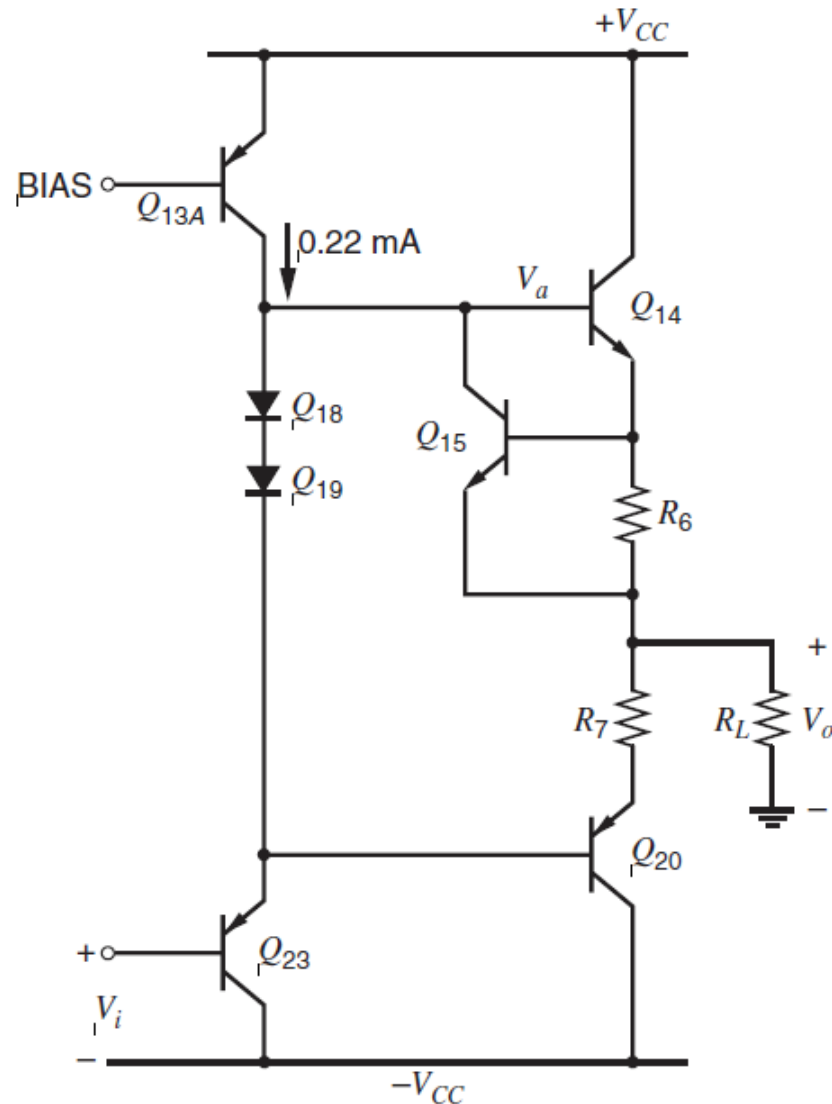
Pojačavač snage u klasi AB sa npn izlaznim tranzistorima



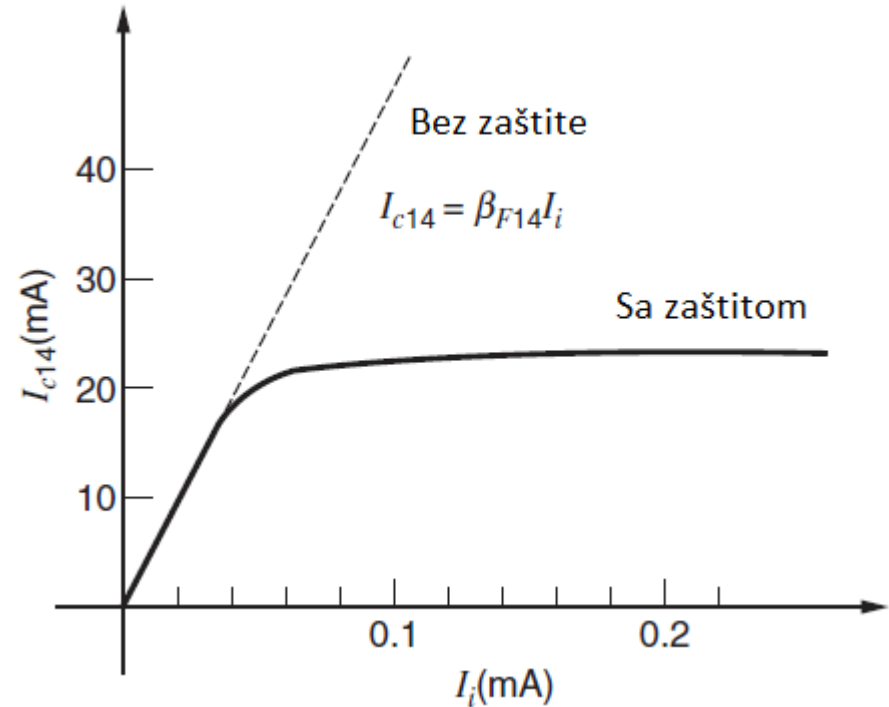
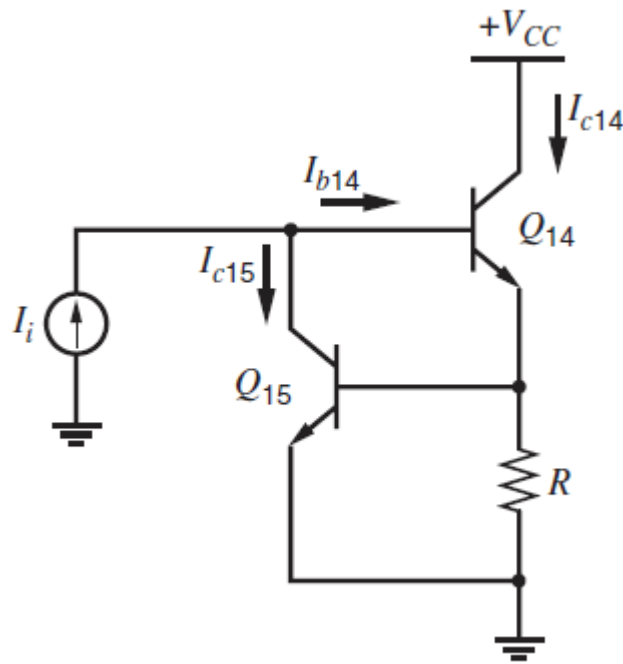
Pojačavač snage sa npn Darlington izlaznim tranzistorima



Pojačavač snage sa gornjom prekostrujnom zaštitom u klasi AB



Rad prekostrujne zaštite u slučaju kratkog spoja potrošača



Kada Q_{15} provede, kolektorska struja Q_{15} smanjuje baznu struju Q_{14} i time kolektorsku struju Q_{14} .

$$I_i = I_{b14} + I_{c15}$$

$$I_{b14} = I_i - I_{c15}$$

$$V_{be15} \simeq I_{c14}R$$

$$I_{c15} = I_{S15} \exp \frac{V_{be15}}{V_T}$$

$$I_{c14} = \beta_{F14} I_{b14} = \beta_{F14} (I_i - I_{c15})$$

$$I_{c14} + \beta_{F14} I_{S15} \exp \frac{I_{c14}R}{V_T} = \beta_{F14} I_i$$

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