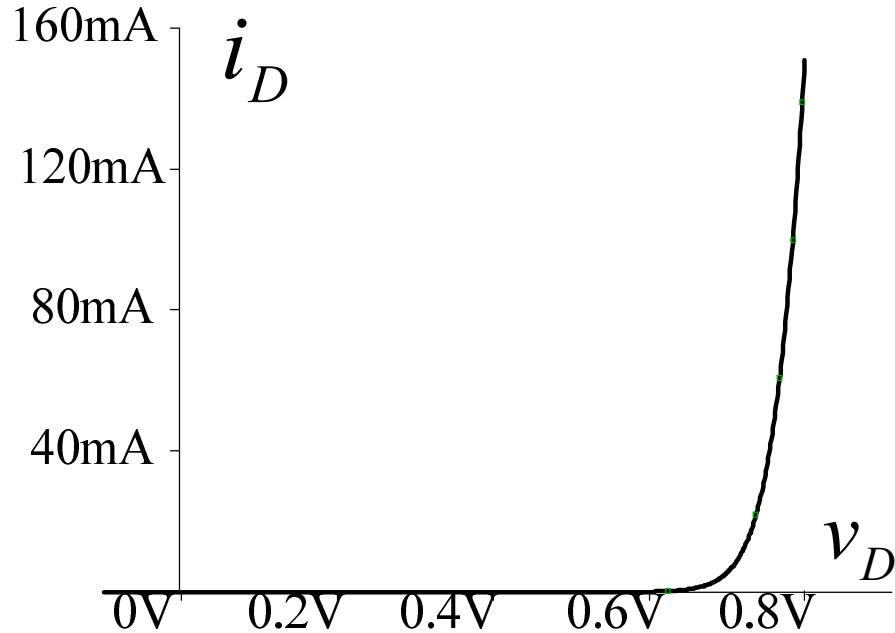
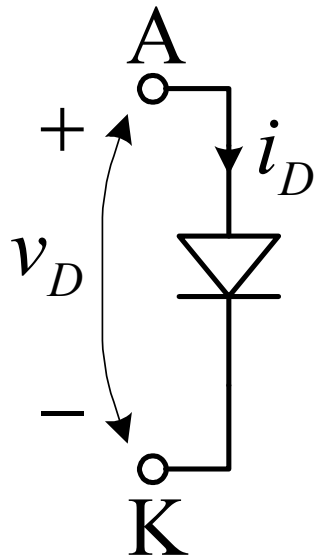


# Uvod

# Poluprovodnička dioda (PN spoj)

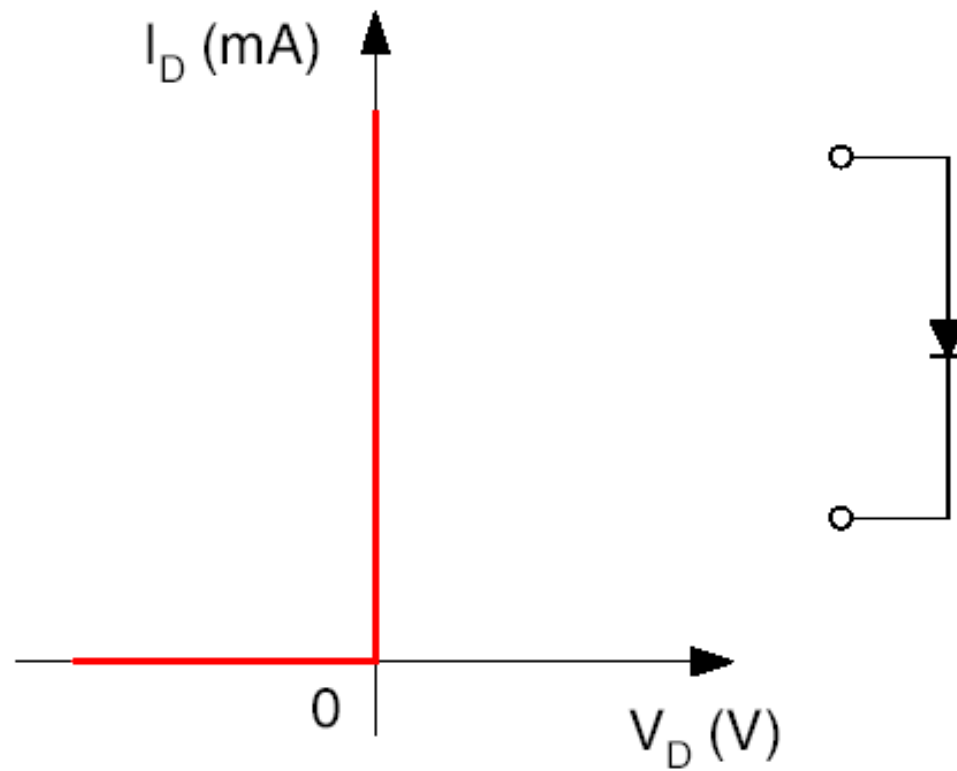


$$i_D = I_S \left( e^{v_D/V_T} - 1 \right) \quad \text{jednosmerna prenosna naponsko strujna karakteristika}$$

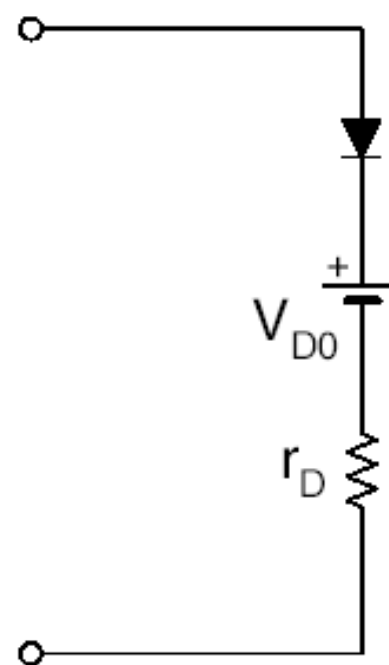
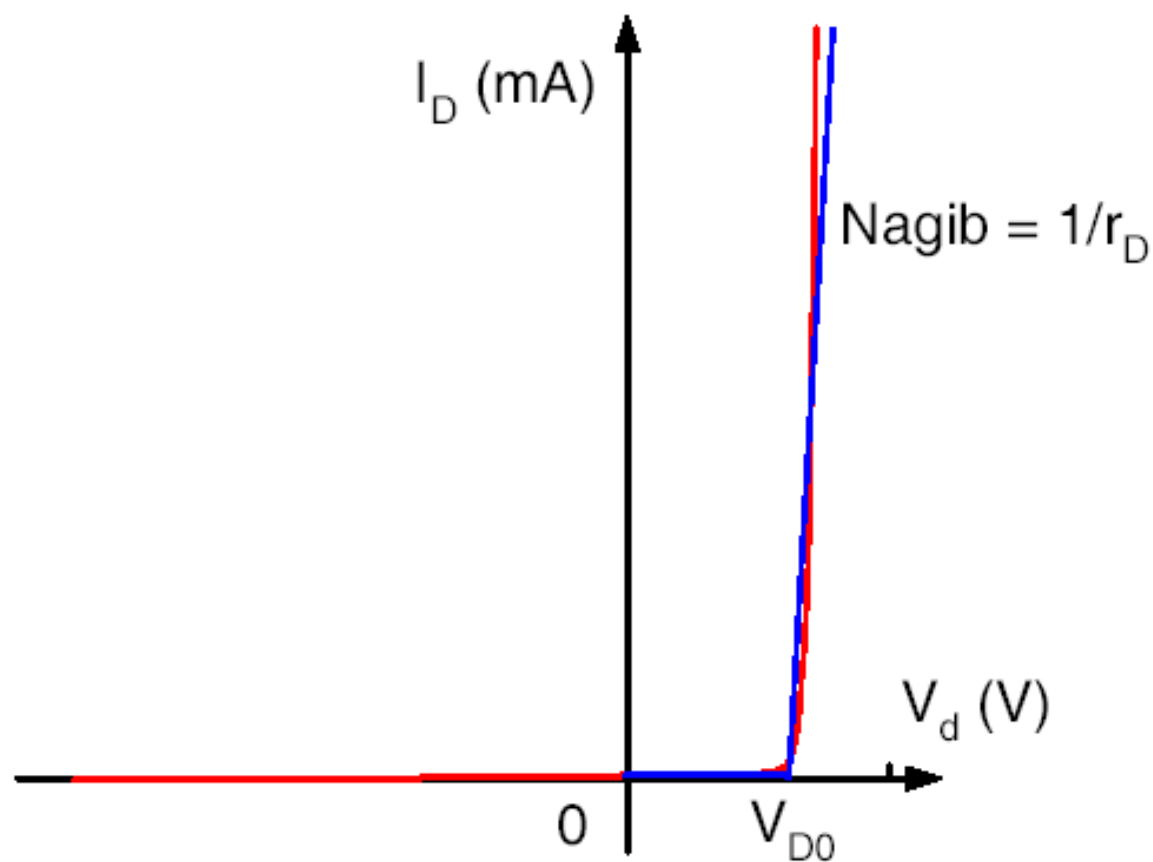
$I_S$  inverzna struja zasićenja, Kod dioda za male snage ova struja je reda  $10^{-15}$  A

$$V_T = kT / q = 25,7 \text{ mV} @ 300 \text{ K}$$

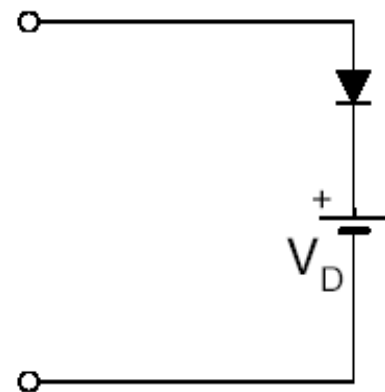
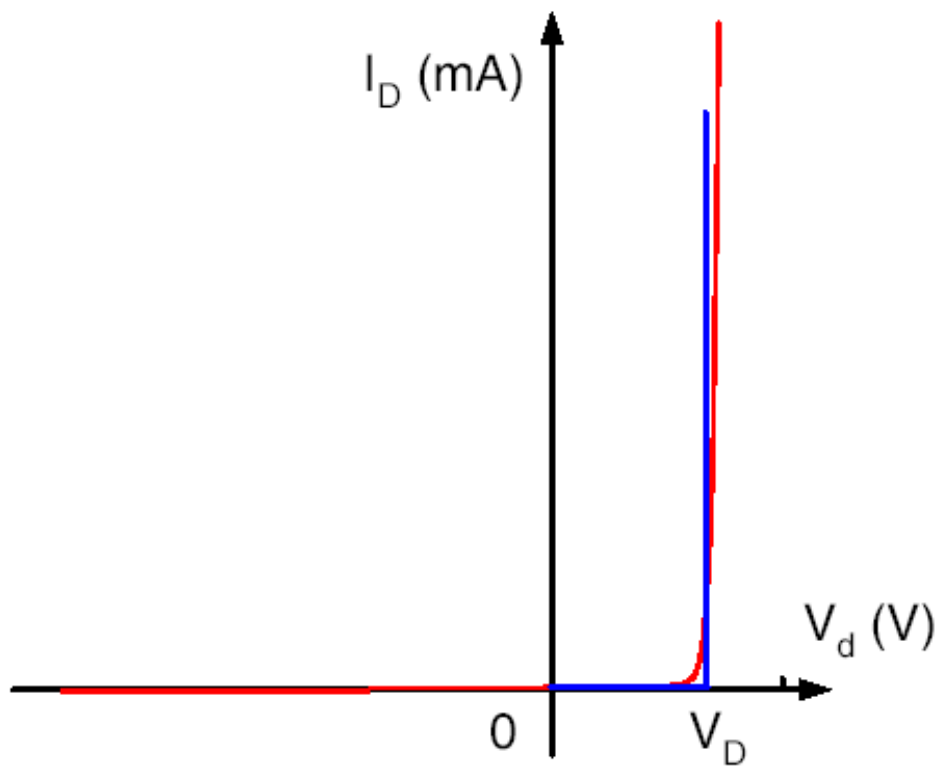
# Statički modeli diode



Idealna dioda

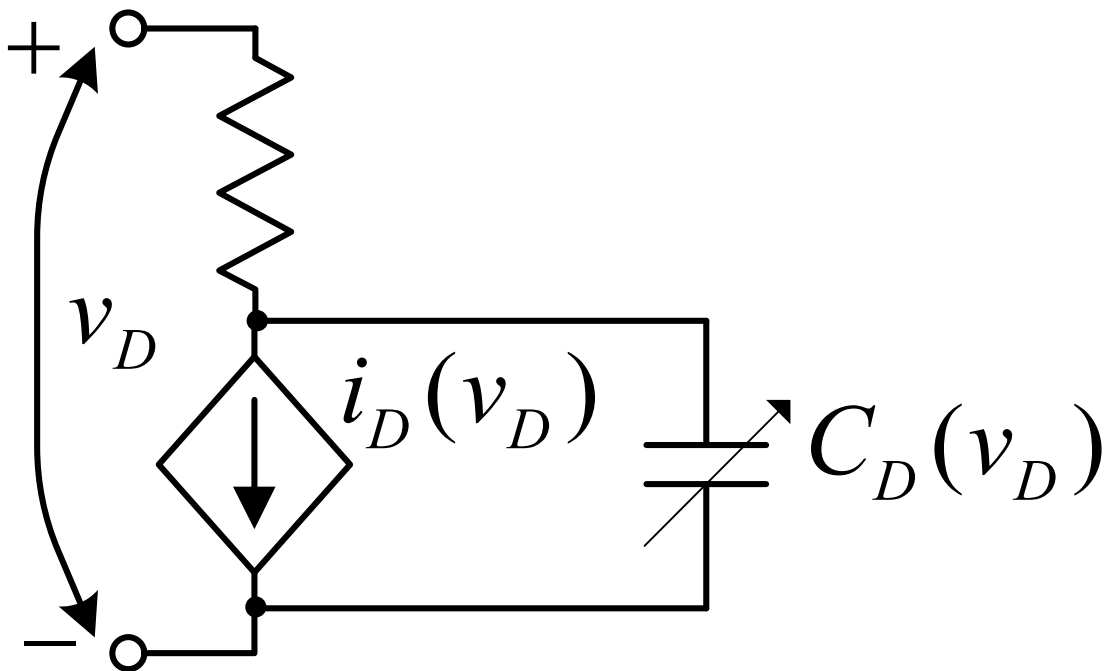
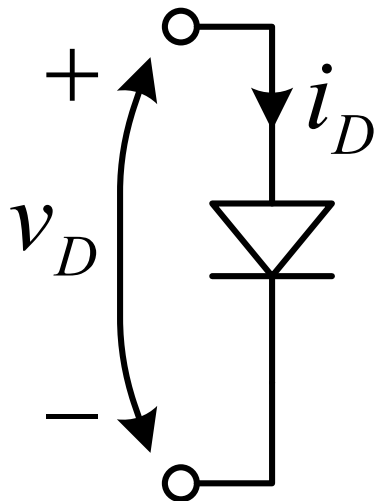


Izlomljeno-linearna aproksimacija



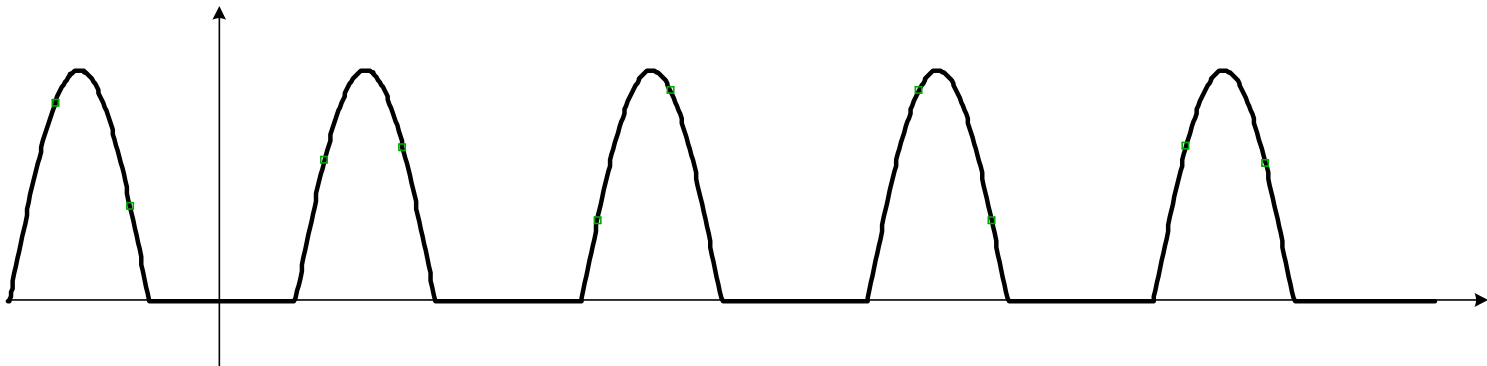
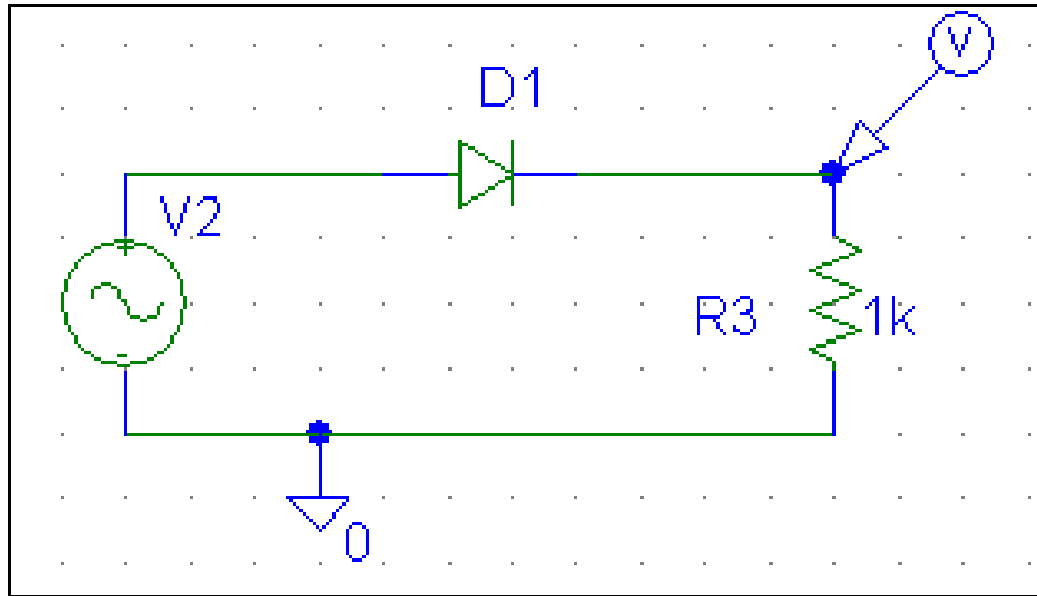
Aproksimacija sa konstantnim naponom

# Dinamički modeli



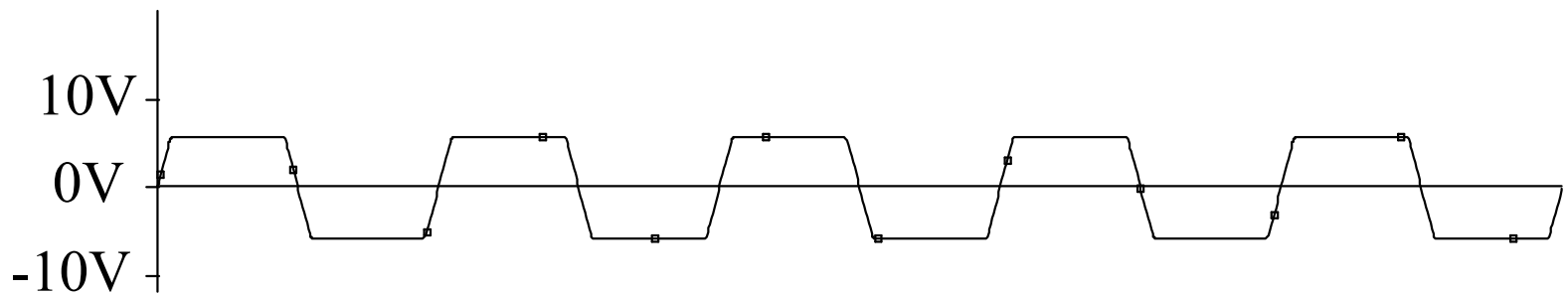
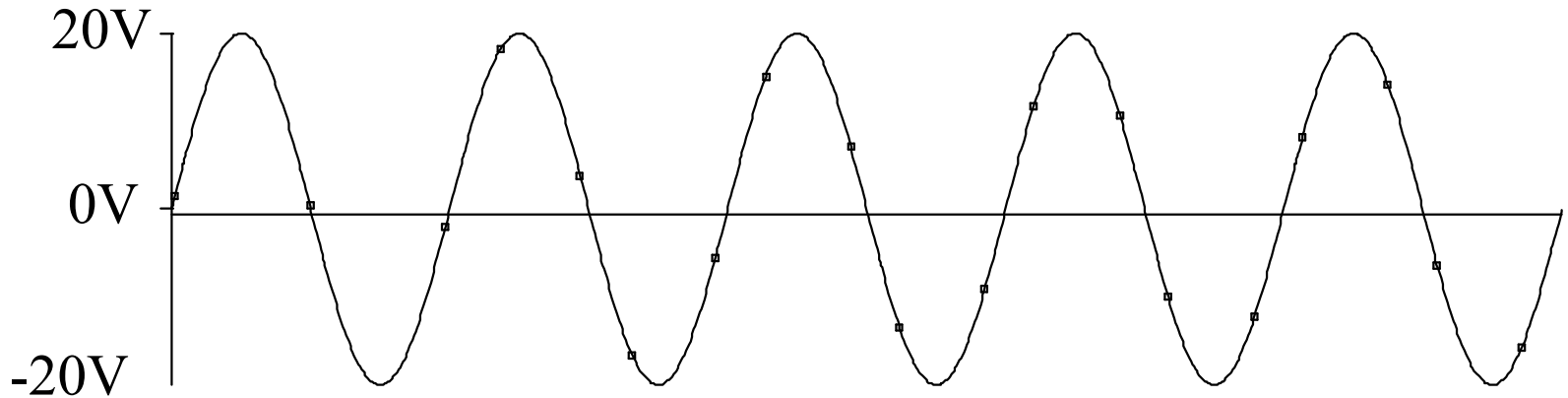
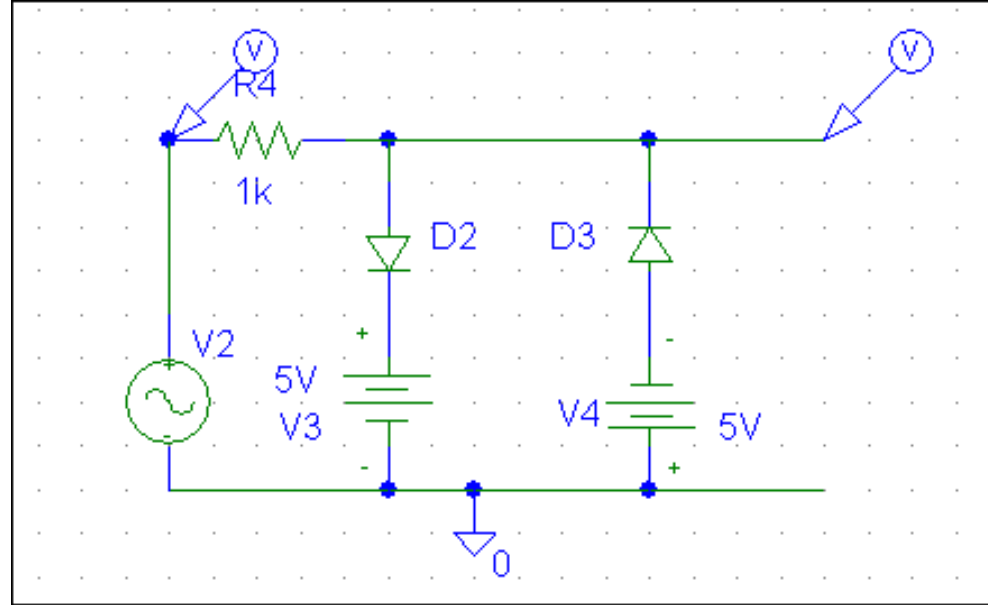
# Primene diode

## - Polutalasno ispravljanje



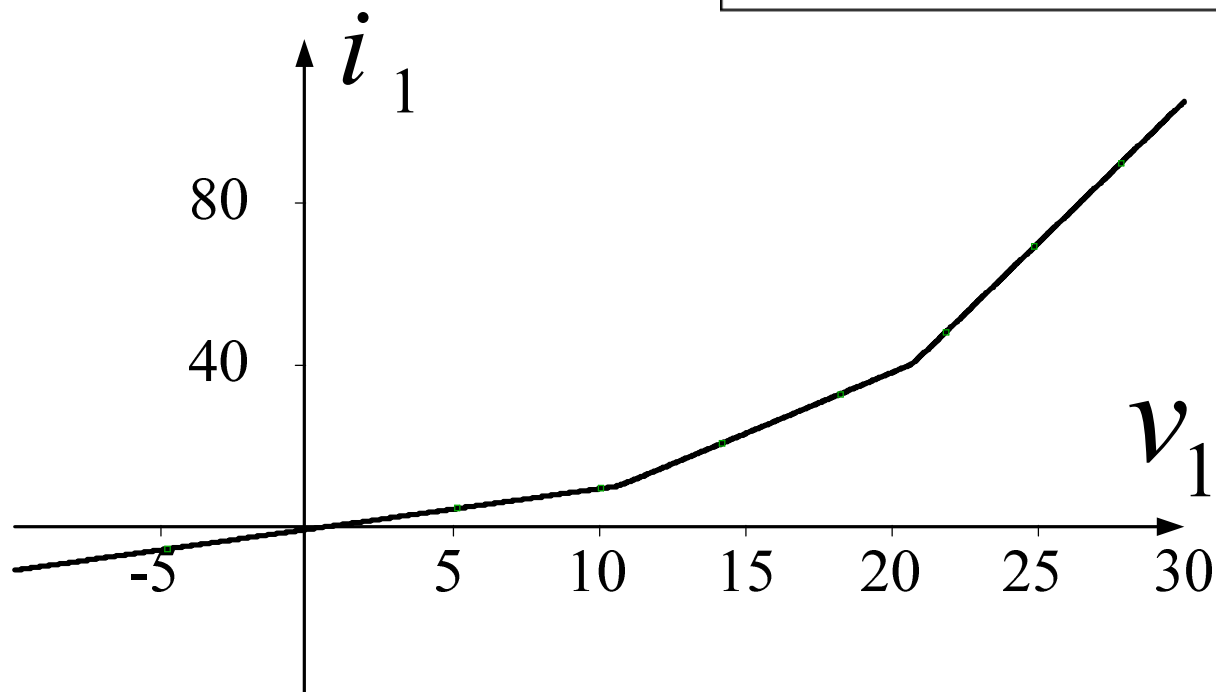
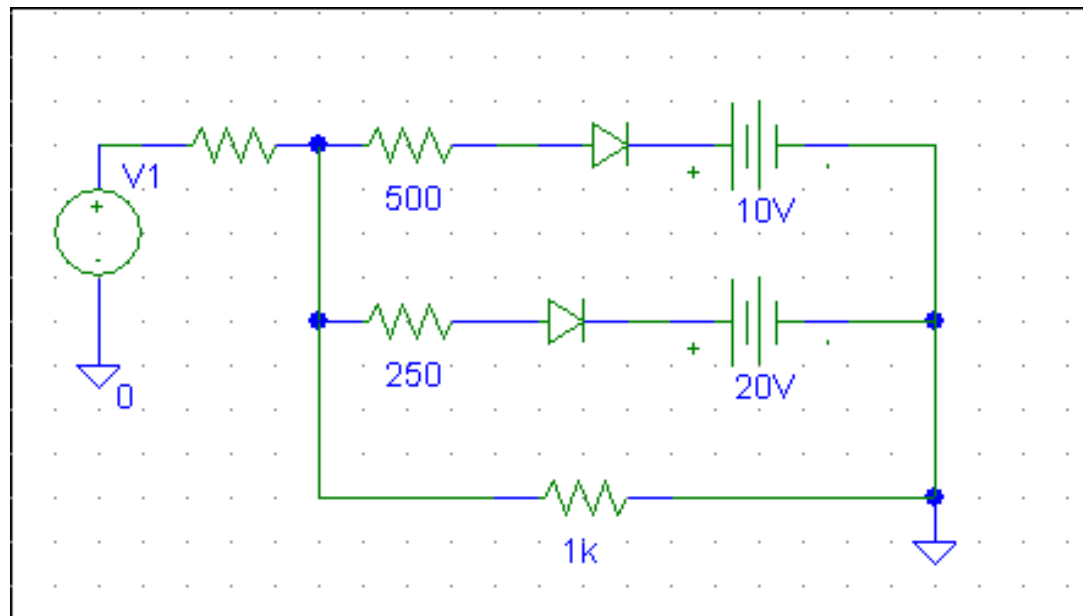
# -Uobličavanje signala

precizni dvostrani  
ograničavač





# Nelinearna otpornost

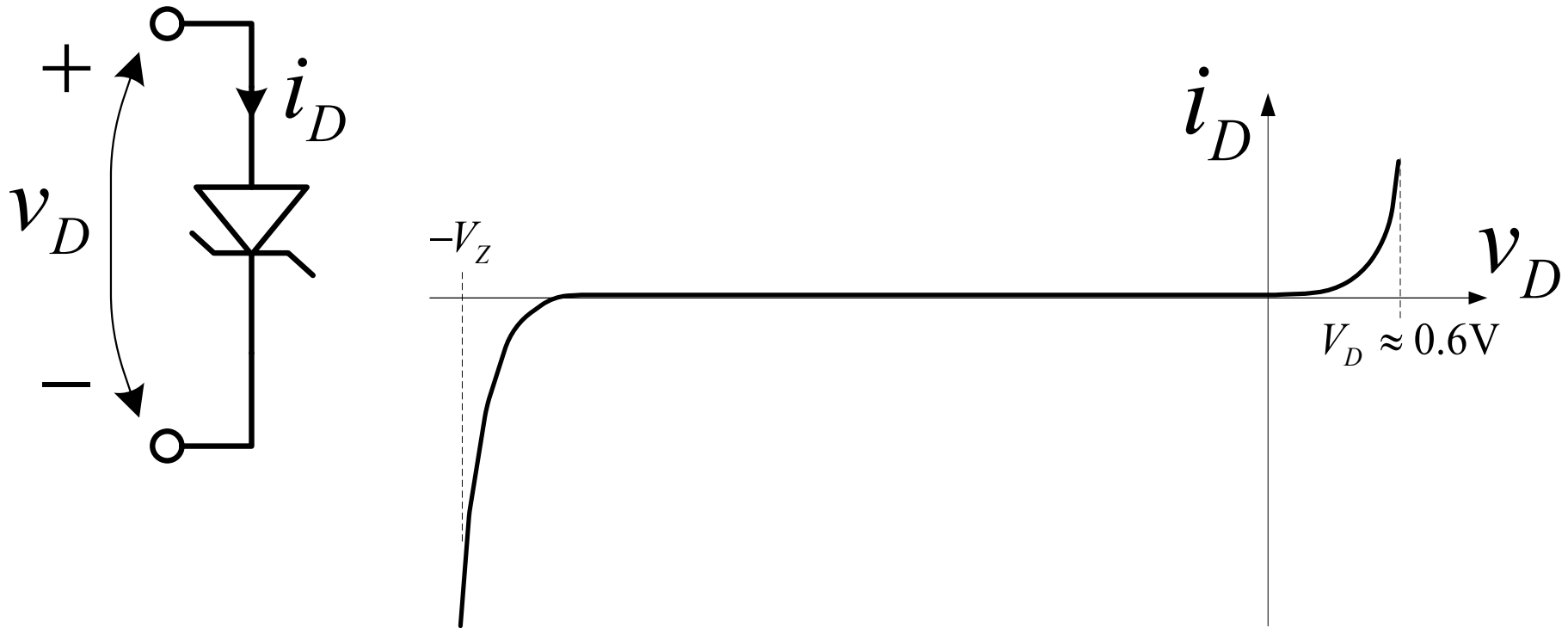


# Karakteristike diode

Symbol	Parameter		Value	Unit
$I_{FRM}$	Repetive Peak Forward Current	$t_p \leq 10\mu s$	30	A
$I_F (AV)$	Average Forward Current*	$T_a = 70^\circ C$ $\delta = 0.5$	1	A
$I_{FSM}$	Surge non Repetitive Forward Current	$t_p = 10ms$ Sinusoidal	30	A
P	Power Dissipation*	$T_a = 70^\circ C$	1.33	W
$T_{stg}$ $T_j$	Storage and Junction Temperature Range		- 40 to +150 - 40 to + 150	$^\circ C$

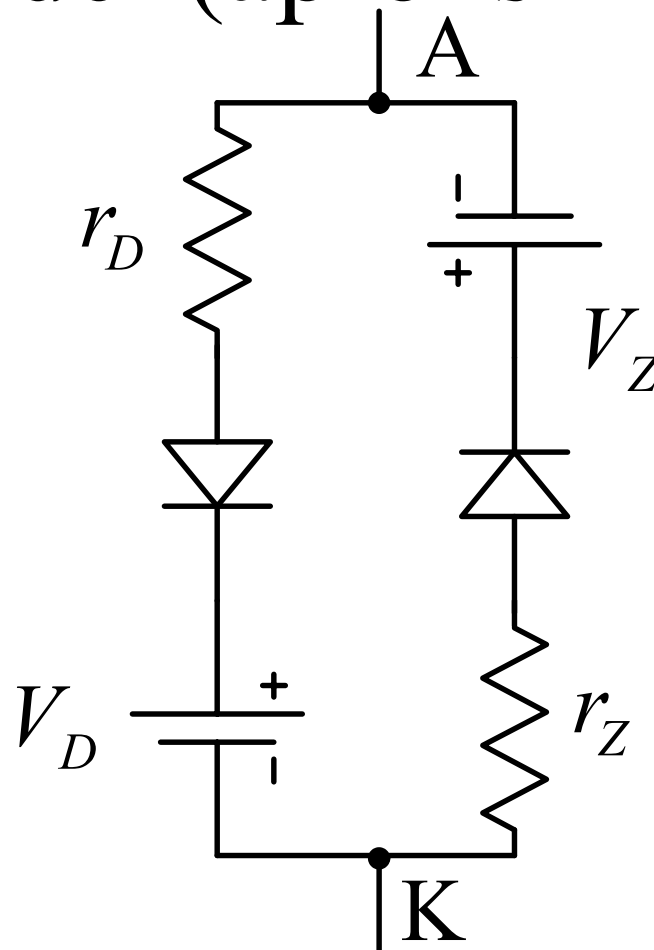
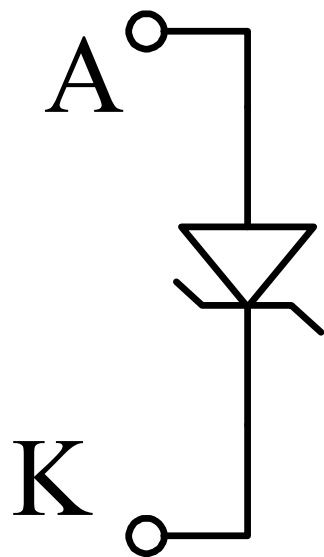
Symbol	Parameter	BYT 01-			Unit	
		200	300	400		
$V_{RRM}$	Repetitive Peak Reverse Voltage	200	300	400	V	
$V_{RSM}$	Non Repetitive Peak Reverse Voltage	220	330	440	V	
$I_R$	$T_j = 25^\circ C$	$V_R = V_{RRM}$			20	$\mu A$
	$T_j = 100^\circ C$				0.5	mA
$V_F$	$T_j = 25^\circ C$	$I_F = 1A$			1.5	V
	$T_j = 100^\circ C$				1.4	

# Proboj diode, Zener dioda



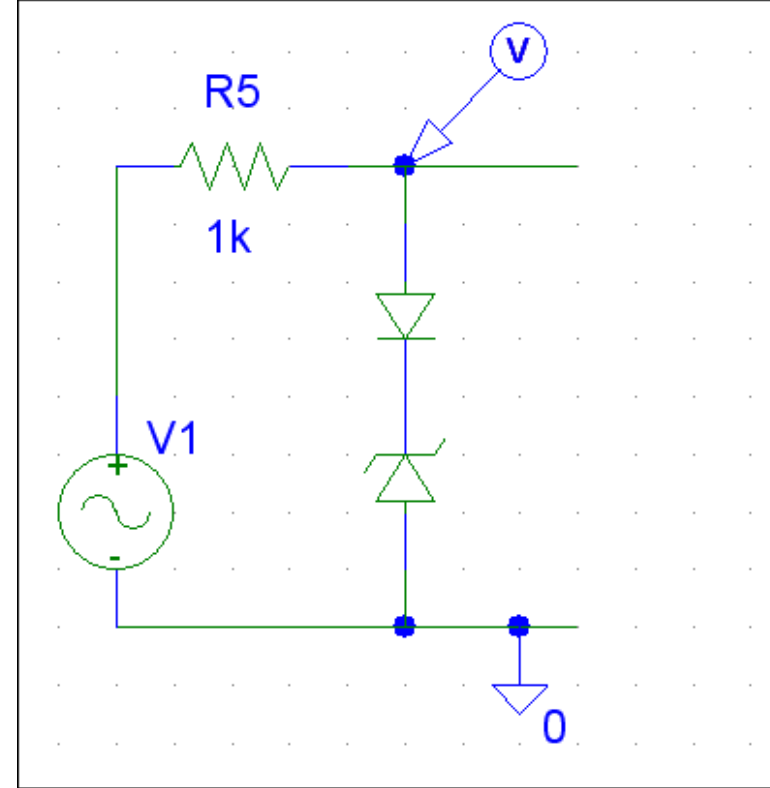
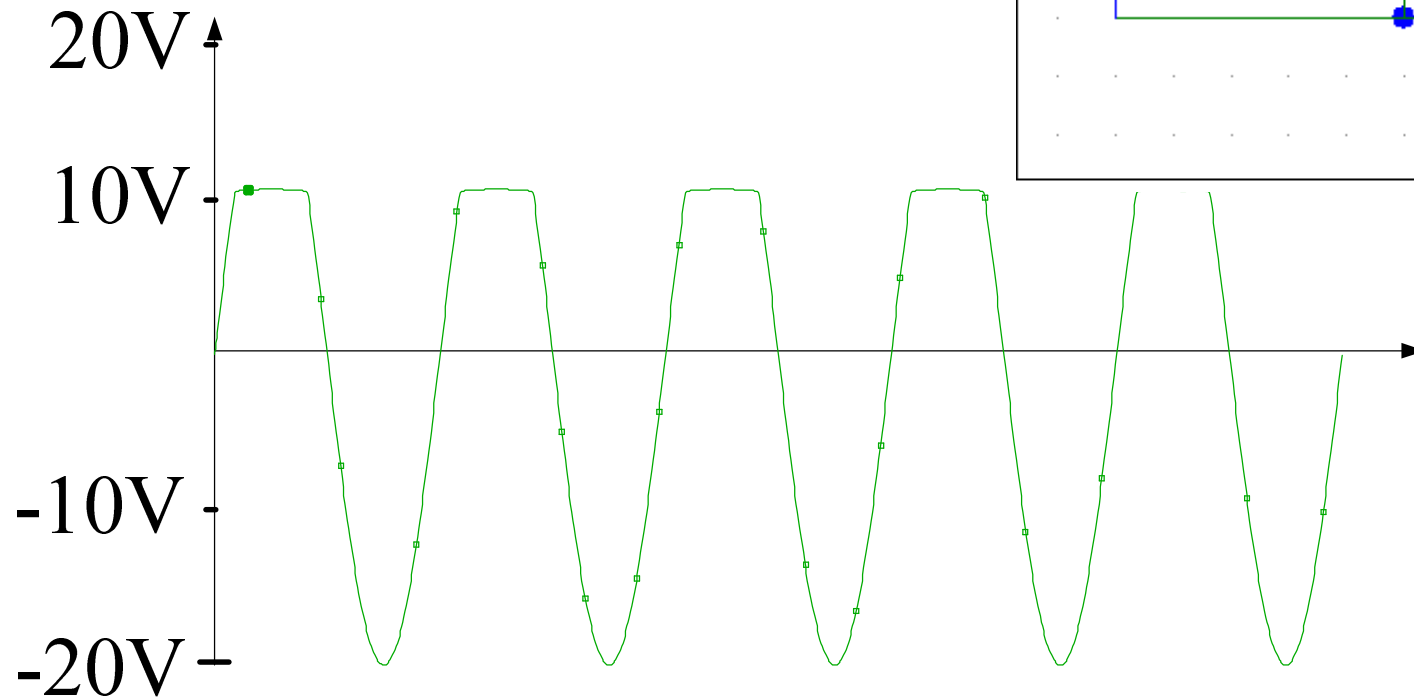
$V_Z$  – karakteristika zener diode

# Statički model (aproksimativni)



# Primene zener diode

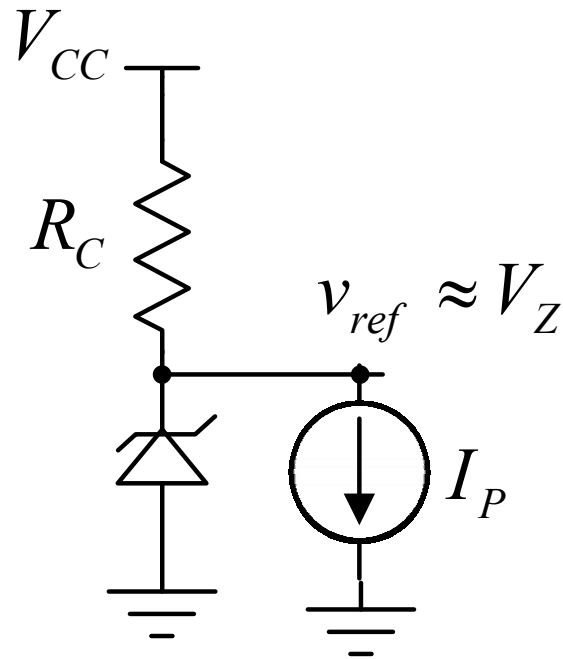
-ograničenje napona



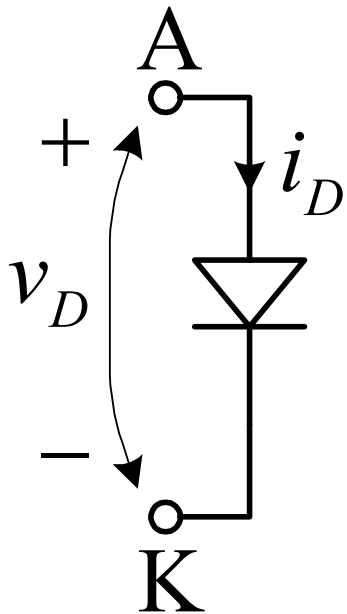
## -Naponske reference

$$v_{ref} \approx V_Z, \quad V_{CC} - R_C I_P > V_Z$$

$$v_{ref} = V_{CC} - R_C I_P, \quad 0 < V_{CC} - R_C I_P < V_Z$$



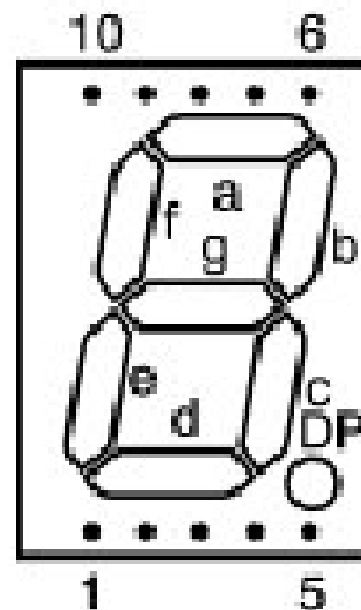
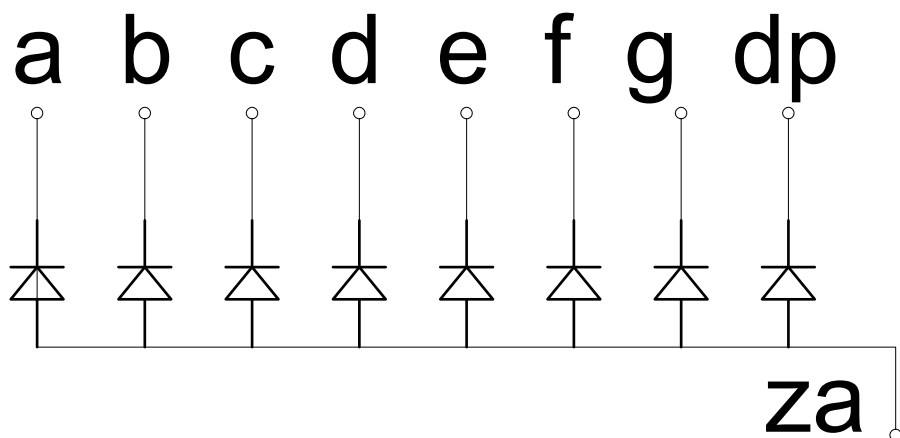
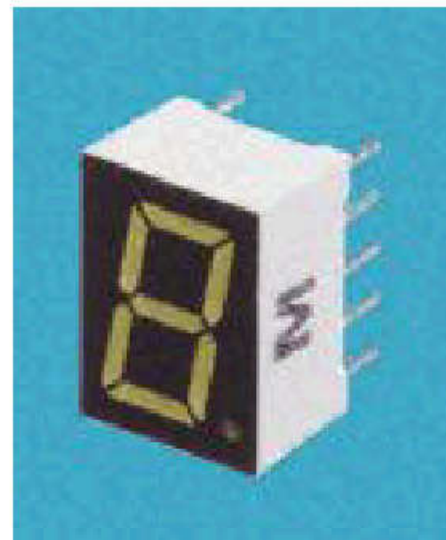
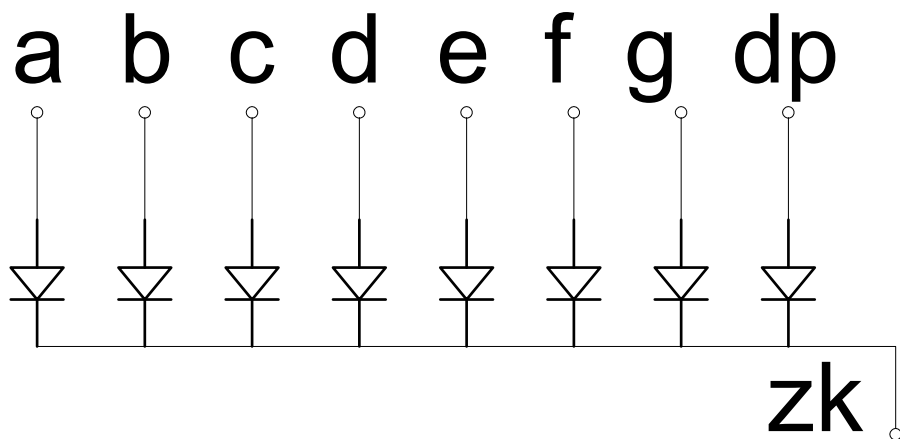
# Led diode



- Standard 10mA
- Low current 1-2mA
- High efficiency
- $v_D$  oko 1.4V

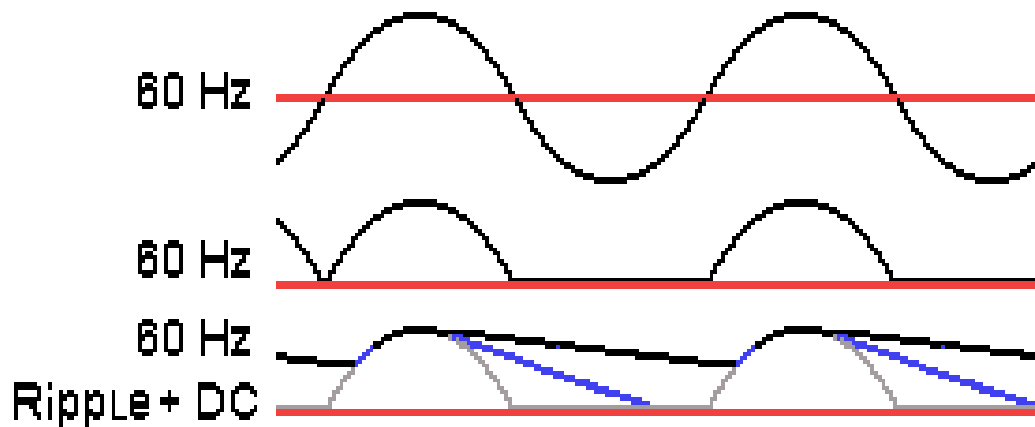
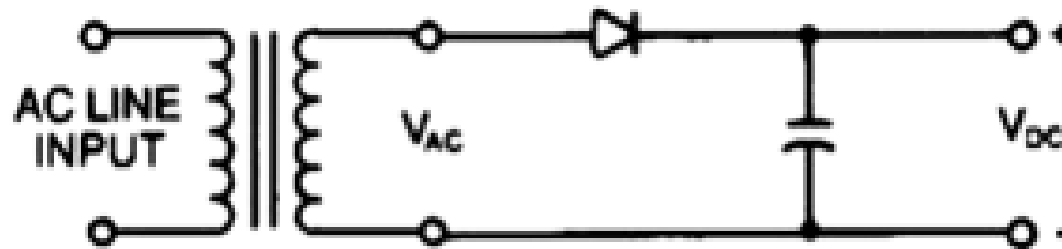


# 7 segmentni led displeji

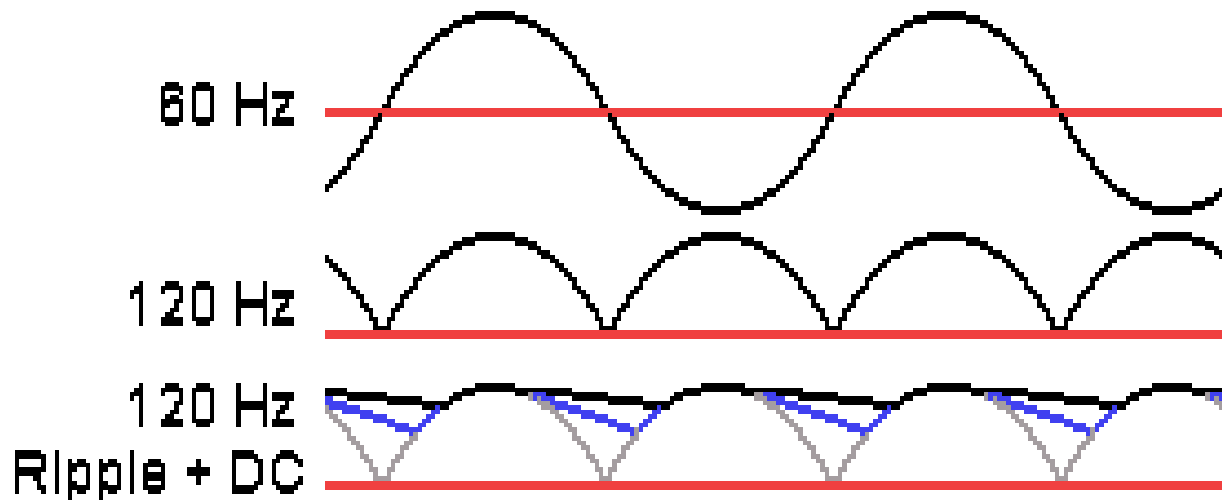
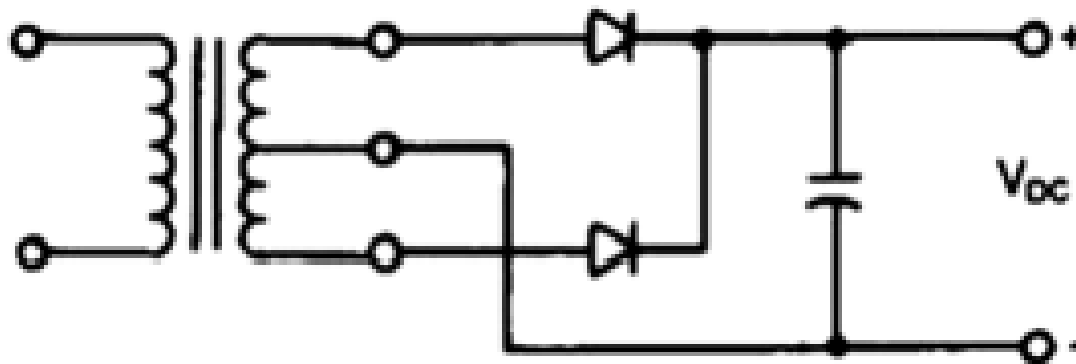




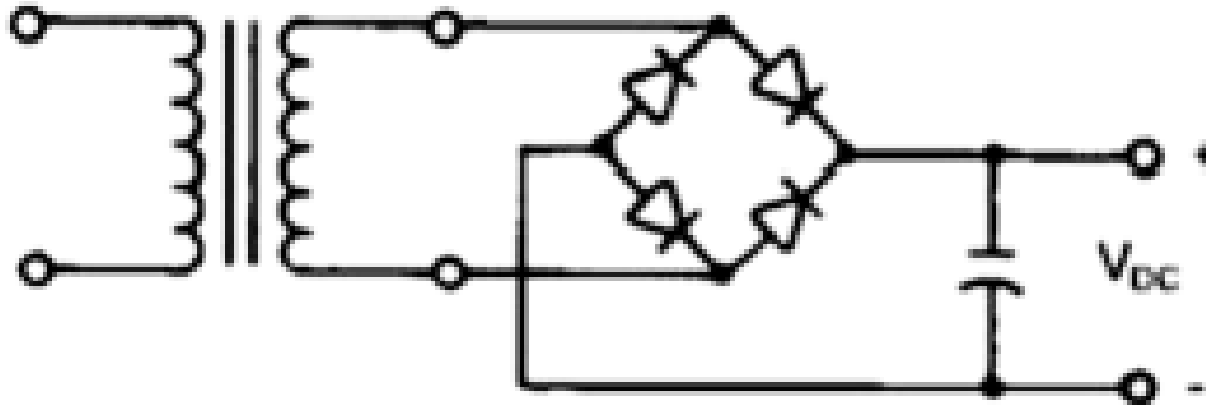
# Jednostrani usmerač



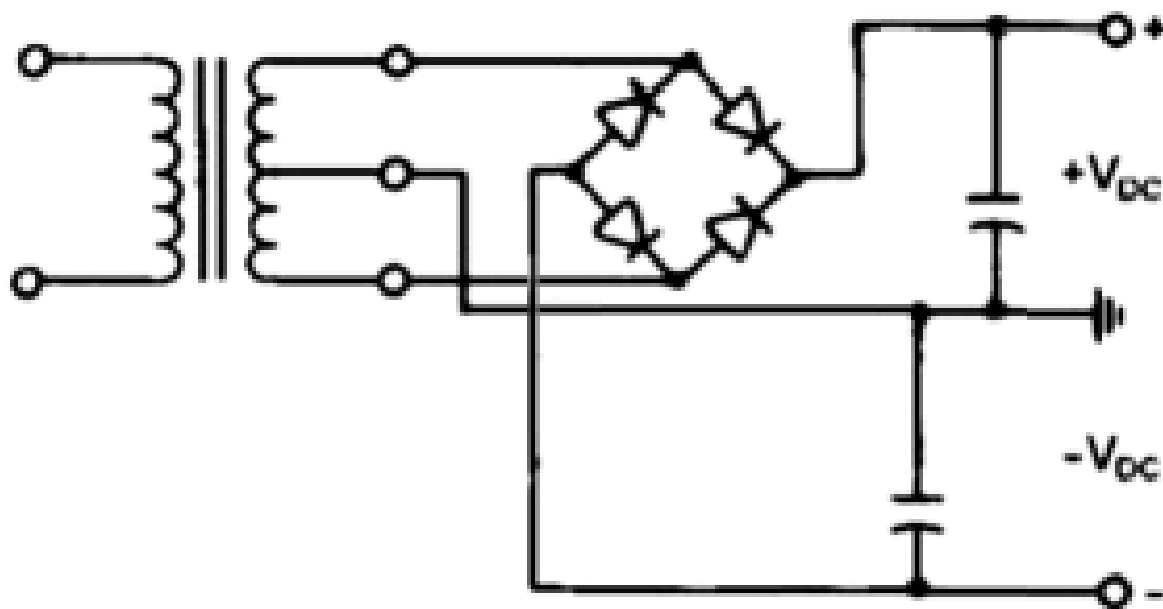
# Dvostrani usmerač sa srednjim izvodom



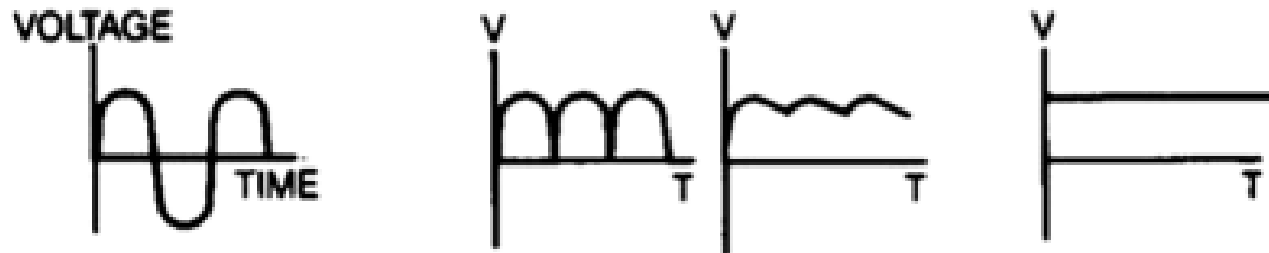
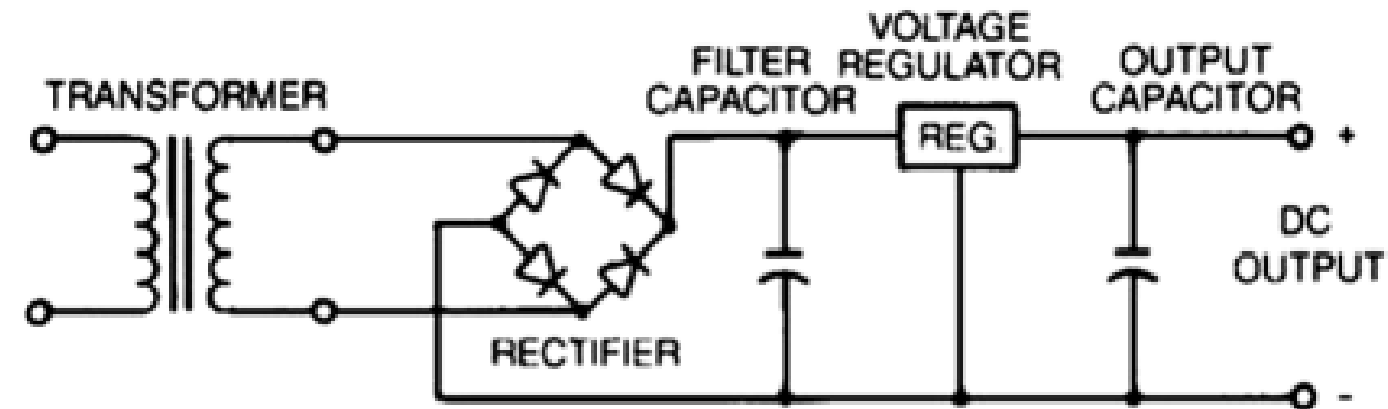
# Dvostrani usmerač sa gretzovim mostom



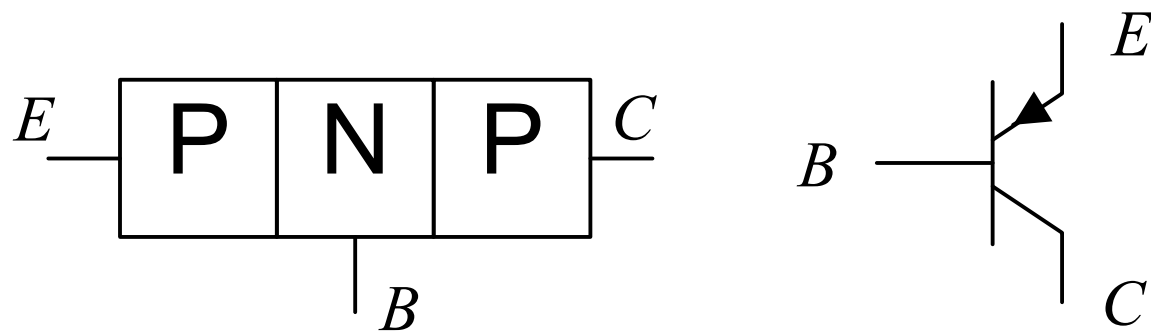
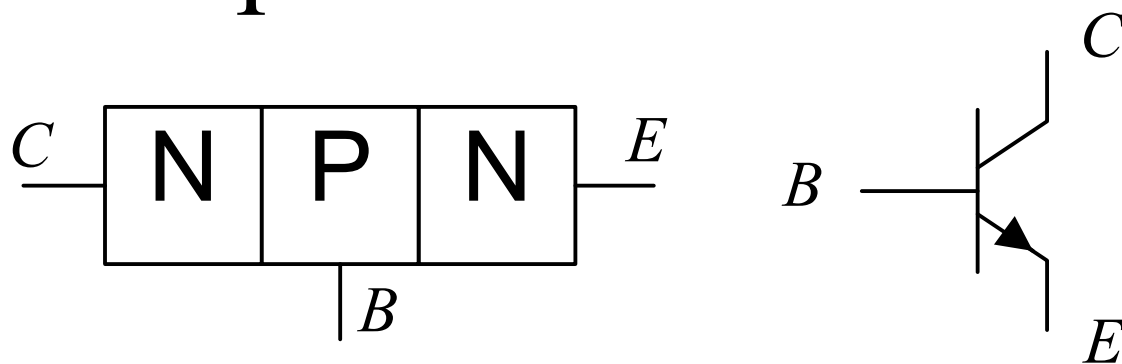
Dvostrani usmerač sa srednjim  
izvodom za pozitivan i negativan  
napon



# Naponska stabilizacija



# Bipolarni tranzistor

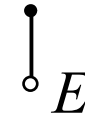


# Režimi rada NPN, statički modeli



- Zakočenje

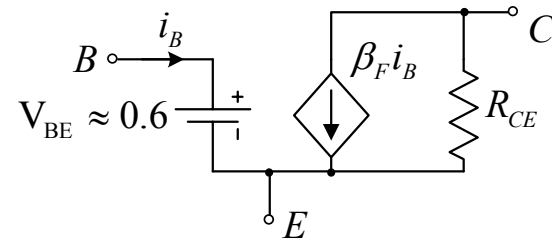
$$0 < v_{BE} < V_{\gamma} \approx 0.5V, v_{CE} > 0$$



- Direktan aktivan

$$v_{BE} > V_{\gamma} \approx 0.5V$$

$$v_{CE} > V_{CES} \approx 0.2V, \beta_F i_B = i_C$$

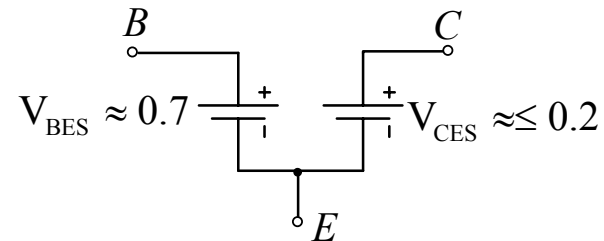


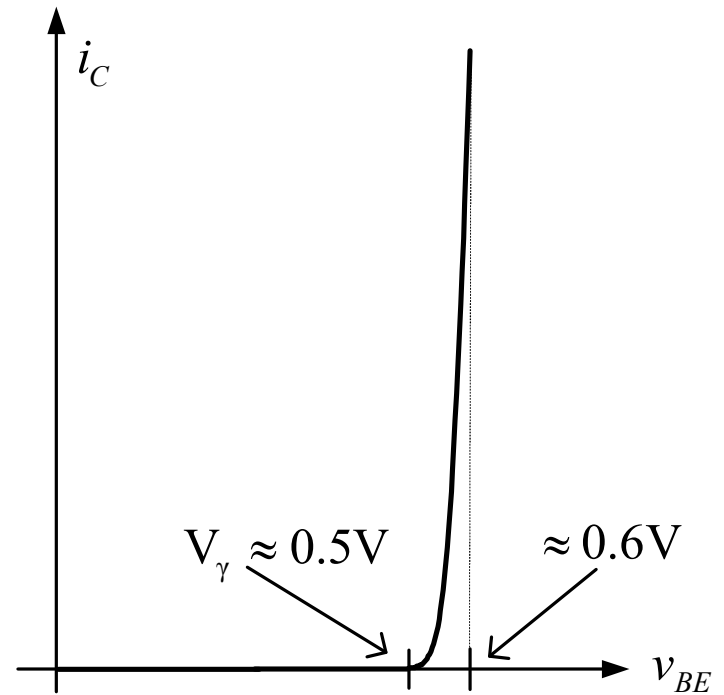
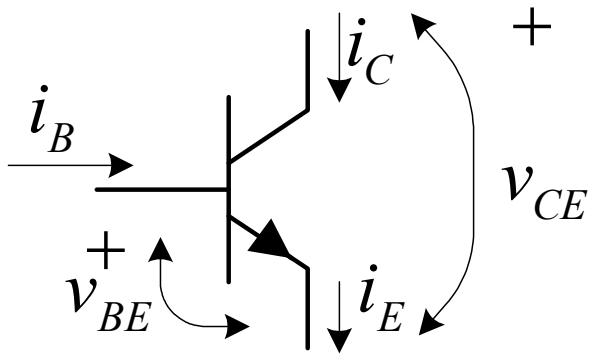
- zasićenje

$$v_{BE} > V_{\gamma} \approx 0.5V$$

$$0 < v_{CE} < V_{CES} \approx 0.2V, \beta_F i_B > i_C$$

- inverzan aktivan





za  $v_{BE} > V_{\gamma} \approx 0.5V$  i  $v_{CE} > V_{CES} \approx 0.2V$

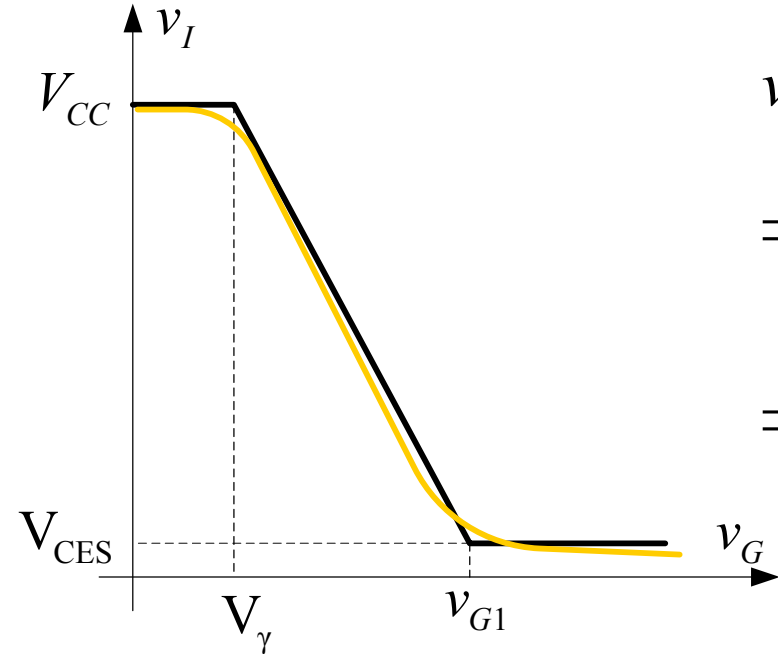
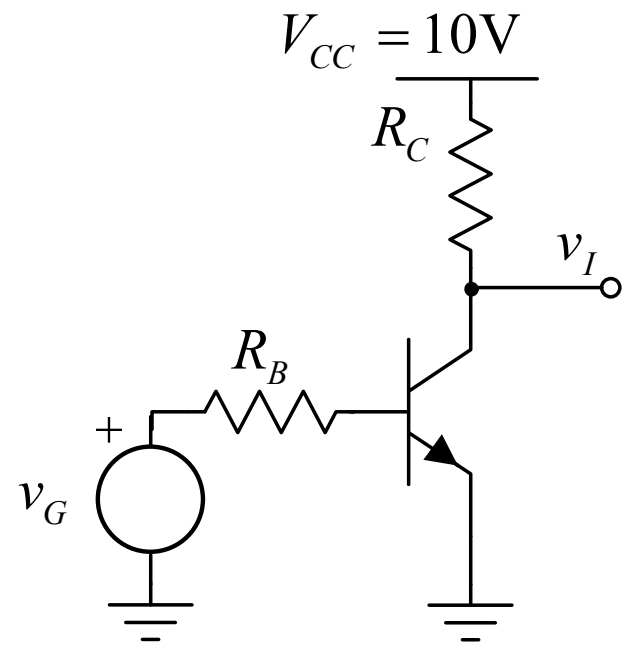
$$i_B = I_{SB} e^{\frac{v_{BE}}{V_T}}$$

$$i_C = I_S e^{\frac{v_{BE}}{V_T}} \left( 1 + \frac{v_{CE}}{V_A} \right) \approx I_S e^{\frac{v_{BE}}{V_T}} = \beta_F i_B$$

$$i_E = i_C + i_B \approx (1 + \beta_F) i_B$$



# Naponski inverter



$$v_G < V_\gamma \Rightarrow i_B = 0 \Rightarrow i_C = 0 \Rightarrow v_I = V_{CC}$$

$$v_G > V_\gamma \wedge v_{CE} > V_{CES} \Rightarrow i_B = \frac{v_G - V_{BE}}{R_B} \Rightarrow$$

$$\Rightarrow i_C = \beta_F i_B \Rightarrow v_I = V_{CC} - R_C i_C =$$

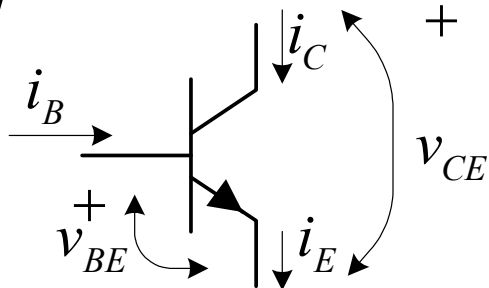
$$= V_{CC} - \beta_F R_C \frac{v_G - V_{BE}}{R_B}$$

$$v_{G1} : V_{CC} - R_C i_{C1} = V_{CC} - R_C \beta_F i_{B1} = V_{CES} \Rightarrow$$

$$\Rightarrow i_{B1} = \frac{V_{CC} - V_{CES}}{R_C \beta_F} = \frac{v_{G1} - V_{BES}}{R_B} \Rightarrow$$

$$\Rightarrow v_{G1} = R_B \frac{V_{CC} - V_{CES}}{R_C \beta_F} + V_{BES}$$

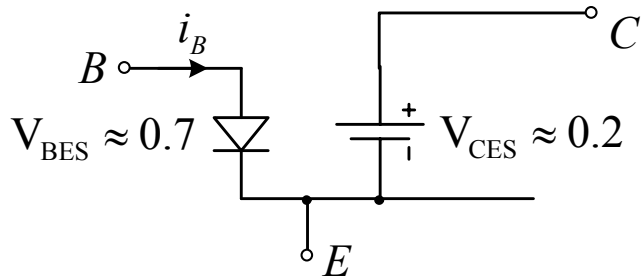
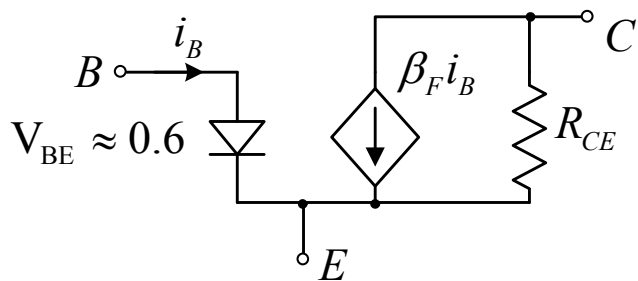
*NPN*



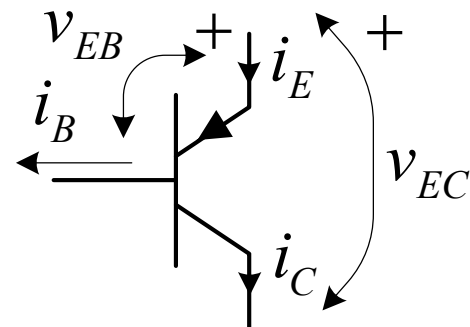
zak.  $v_{BE} < V_\gamma$

dar:  $v_{BE} \approx 0.6V$

$$\beta_F i_B = i_C$$



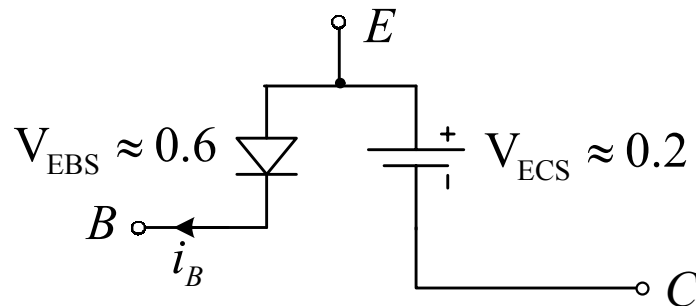
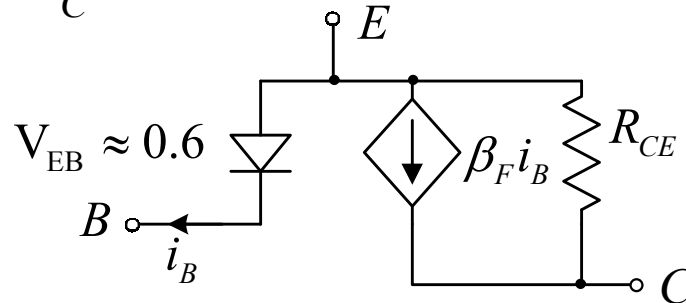
*PNP*



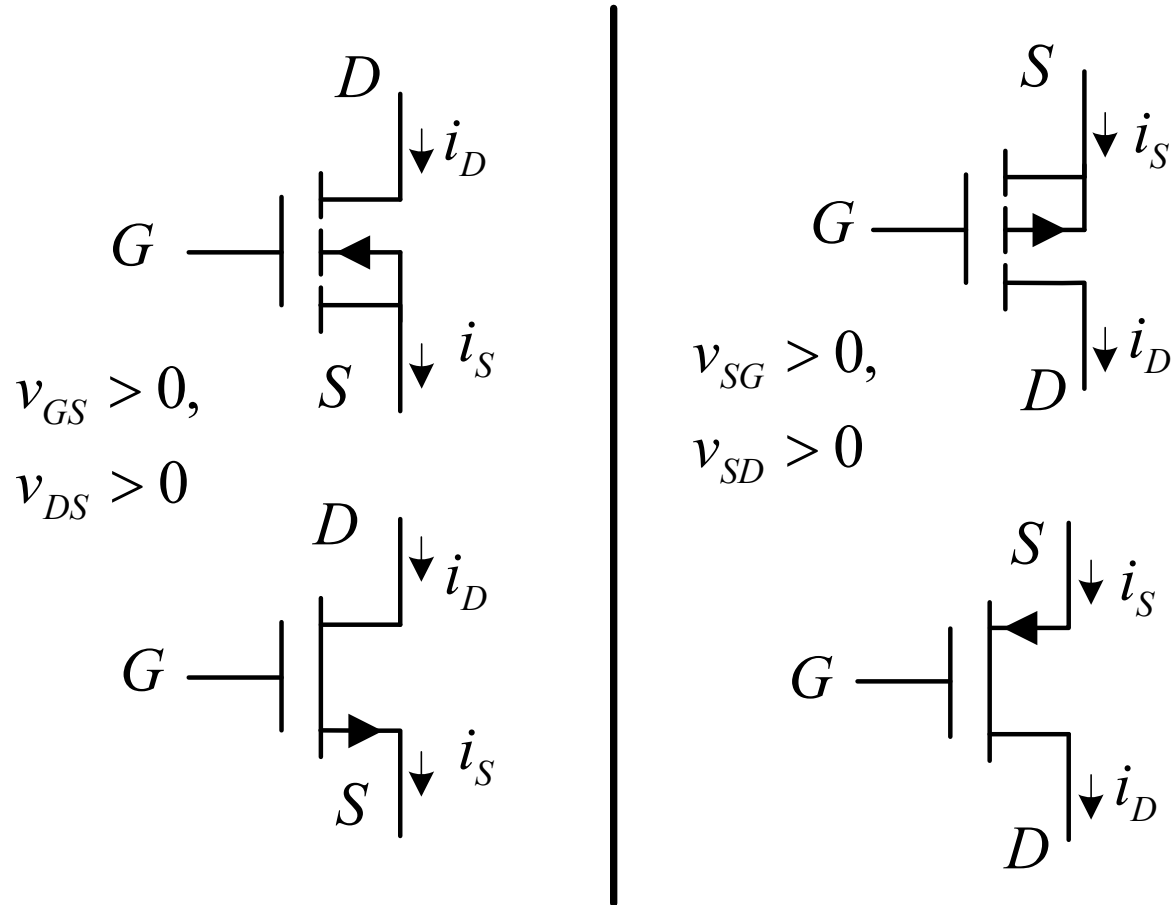
zak.  $v_{EB} < V_\gamma$

dar:  $v_{EB} \approx 0.6V$

$$\beta_F i_B = i_C$$



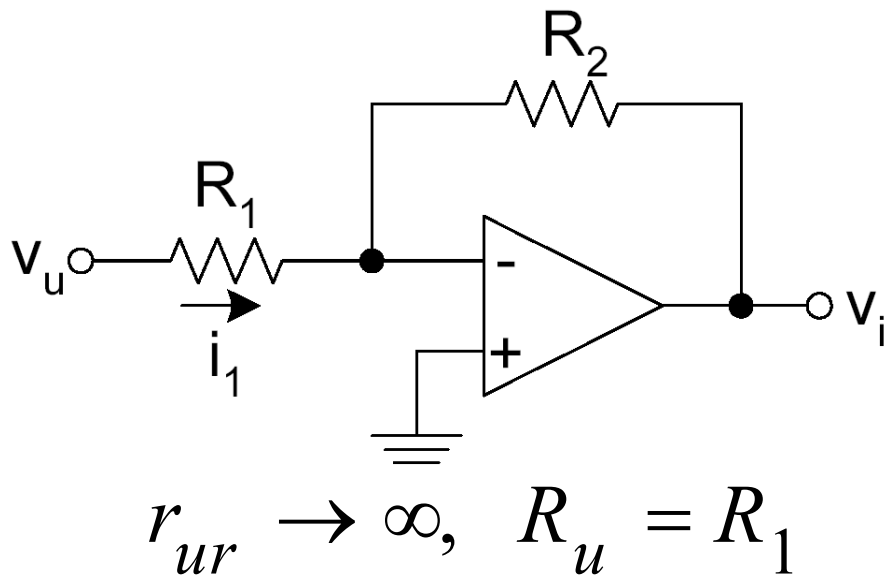
# MOS FET tranzistori metal oxide semiconductor



# Operacioni pojačavač

- Pojačanje
- ulazna i izlazna otpornost,
- Model, model sa napajanjem
- Jednosmerna prenosna karakteristika
- negativna povratna sprega, A i  $\beta$  mreža,
- koristi velikog pojačanja

## Invertujući pojačavač

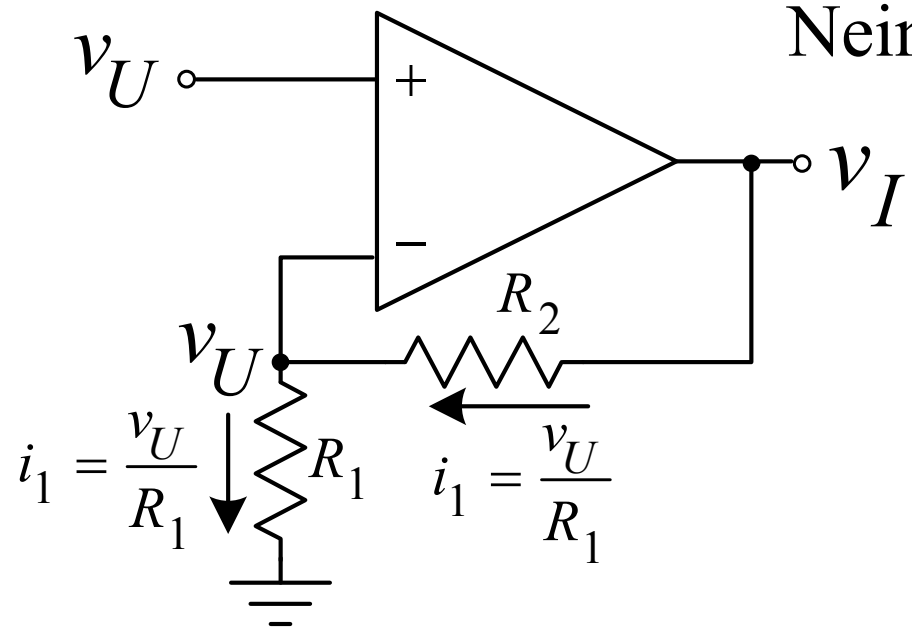


$$i_1 = \frac{v_u}{R_1}$$

$$v_i = -R_2 i_1 = -\frac{R_2}{R_1} v_u$$

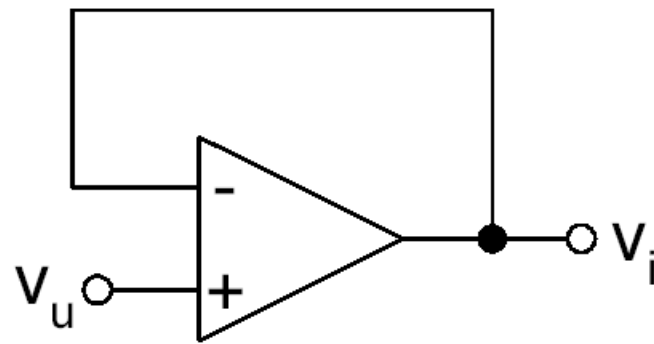
$$R_1 = R_2 \Rightarrow a_r = -1$$

## Neinvertujući pojačavač

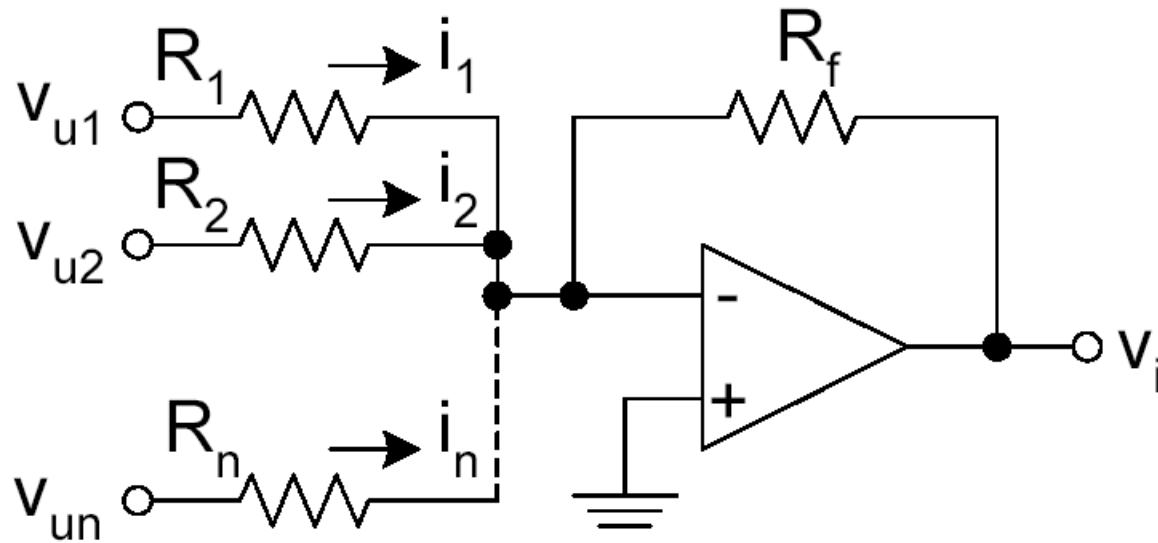


$$v_I = v_U + R_2 i_1 = v_U + R_2 \frac{v_U}{R_1}$$

$$= v_U \left( 1 + \frac{R_2}{R_1} \right) \Rightarrow a_r = 1 + \frac{R_2}{R_1}$$

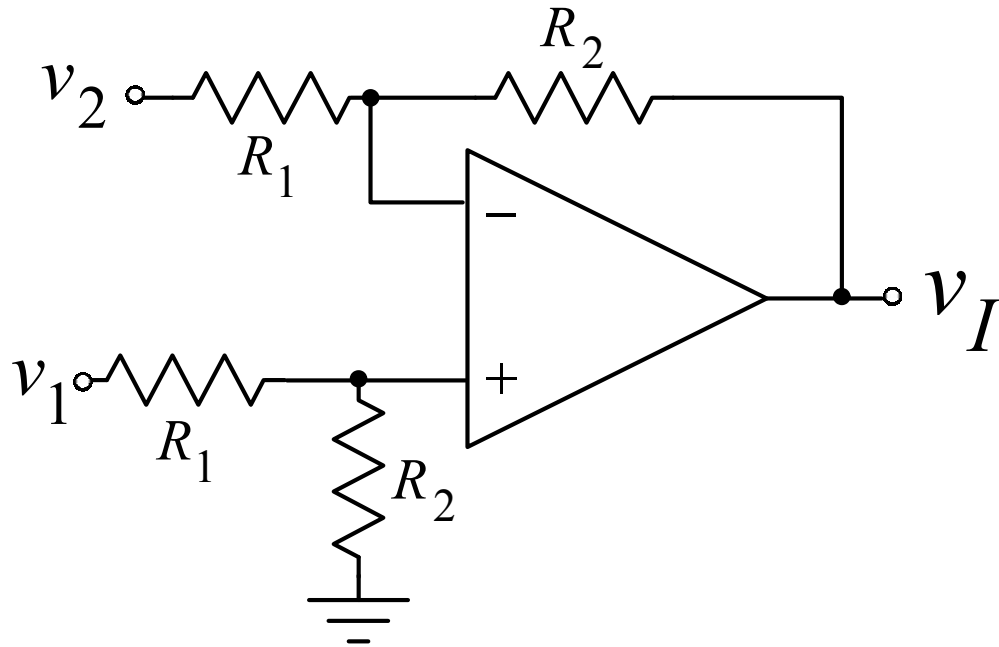


**Slika 10.8: Jedinični pojačavač.**



$$i_k = \frac{v_{uk}}{R_k}, k = 1, 2, \dots, n \quad v_i = -R_f \sum_{k=1}^n i_k = -R_f \sum_{k=1}^n \frac{v_{uk}}{R_k}$$

## Precizni diferencijalni pojačavač



$$v_I = \frac{R_2}{R_1} (v_1 - v_2)$$

# Instrumentacioni pojačavač

