Fakulta biomedicínského inženýrství – Teoretická elektrotechnika

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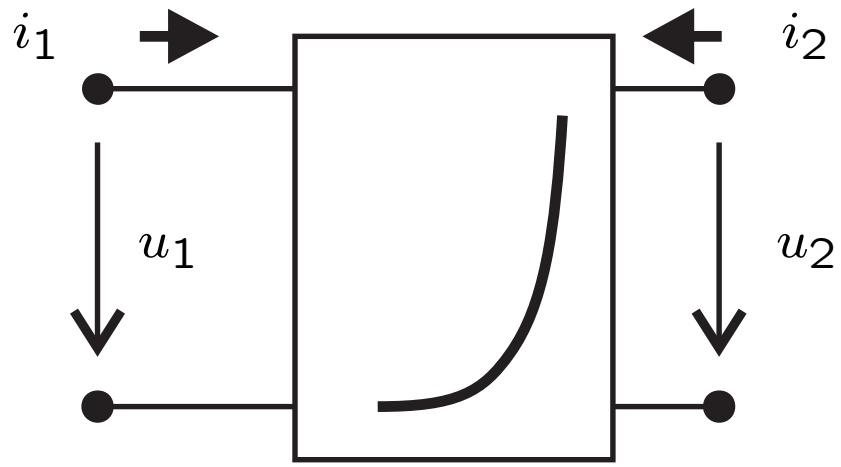
Léto 2020

9. Nelineární obvody – dvojbrany

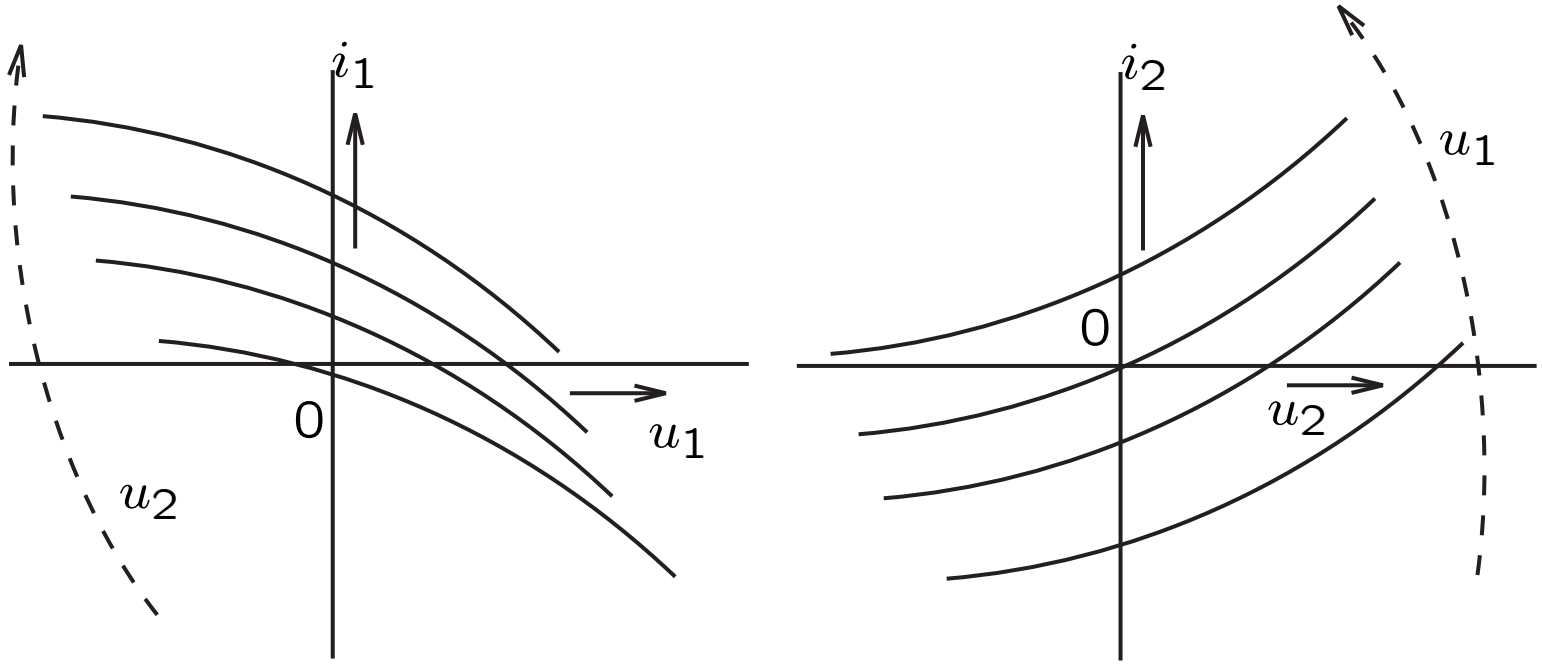
Obvodové veličiny nelineárního dvojbranu



$$i_1 = Y_1(u_1, u_2)$$

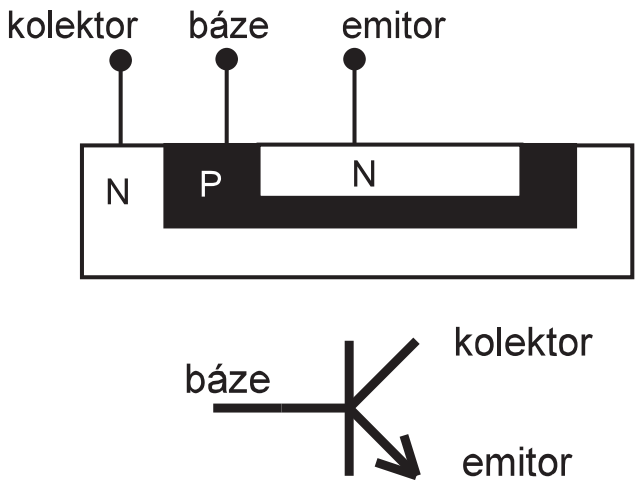
$$i_2 = Y_2(u_1, u_2)$$

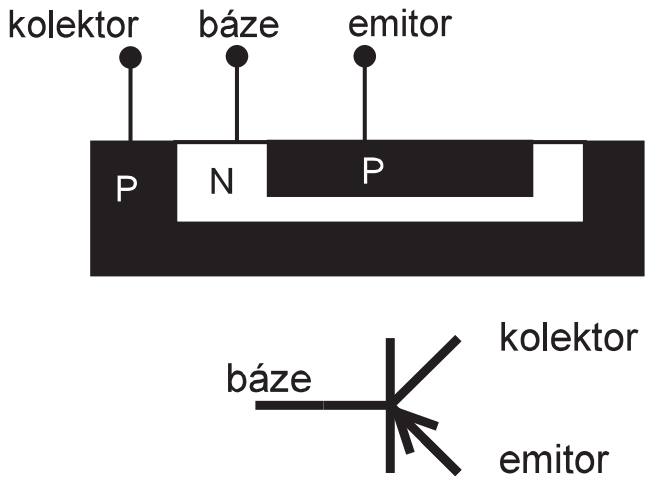
Závislosti obvodových veličin u nelineárního dvojbranu (**Y**)



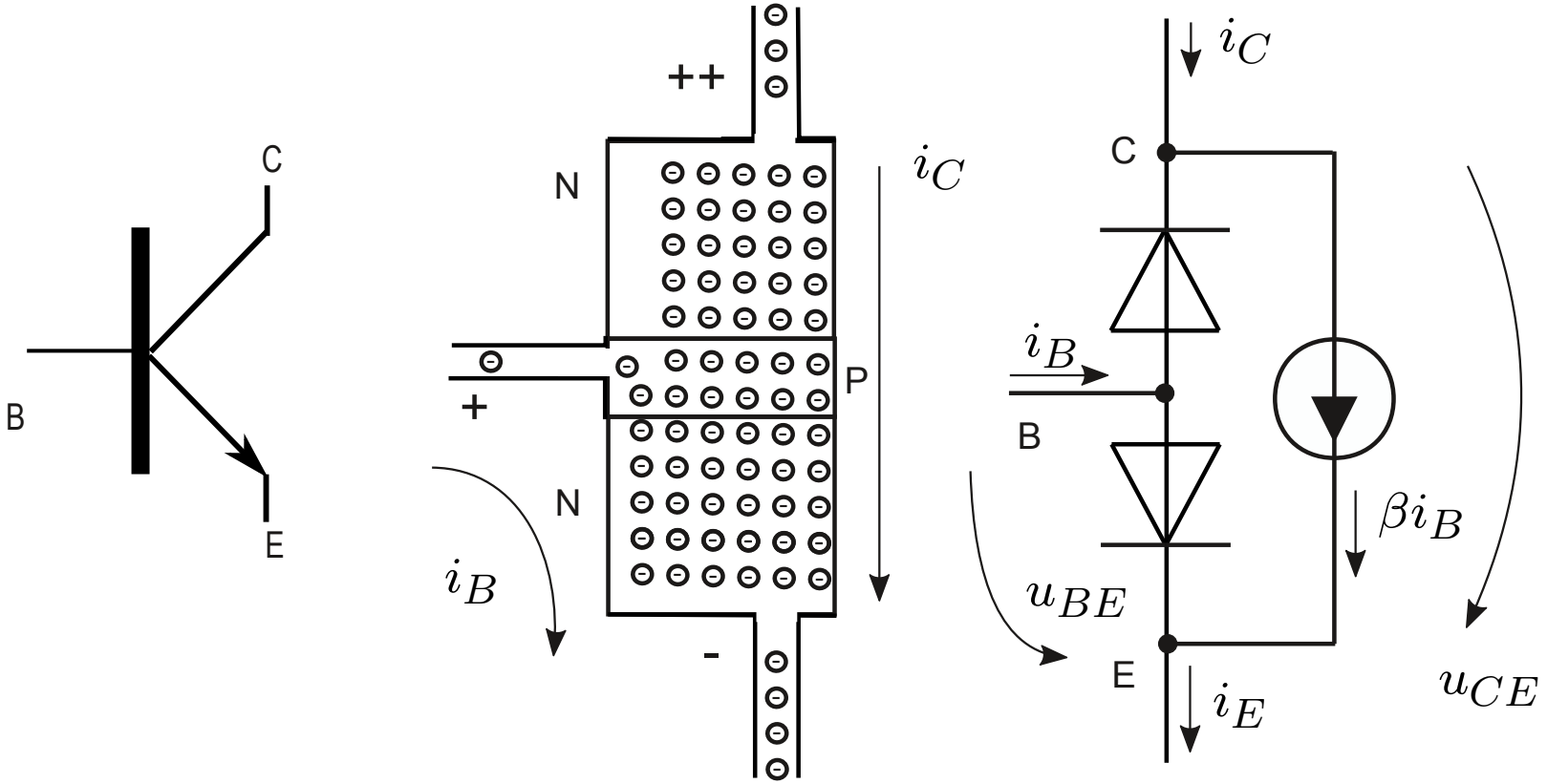
Parametrická soustava charakteristik (např. voltampérových)

Struktura bipolárního tranzistoru



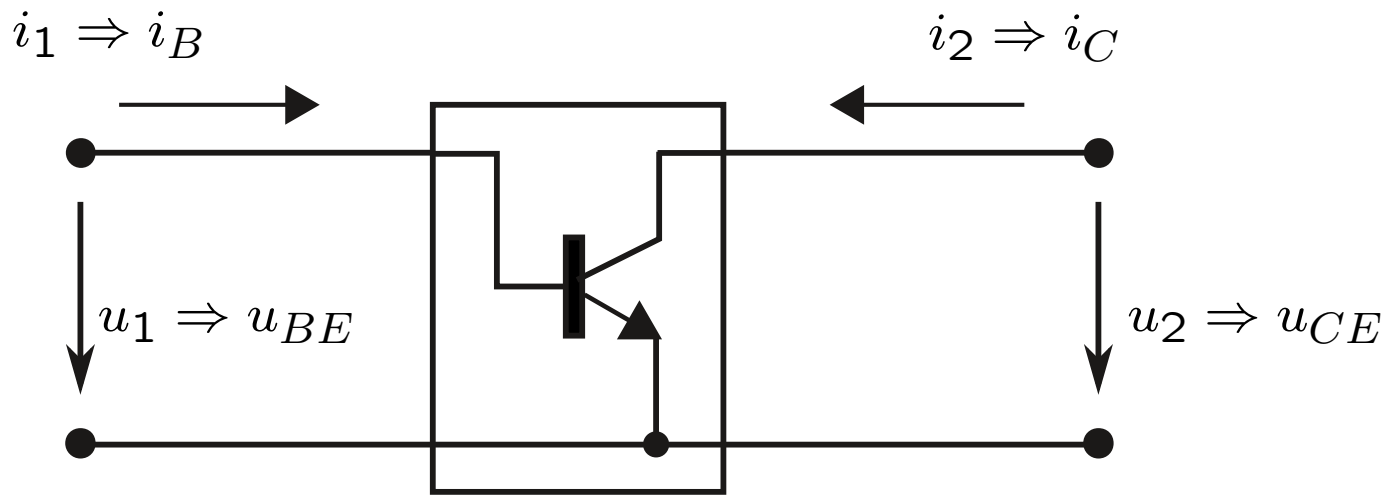


Nosiče náboje ve struktuře NPN bipolárního tranzistoru, když $U_{CE} > U_{BE} > 0$ – tranzistorový jev (aktivní oblast činnosti)

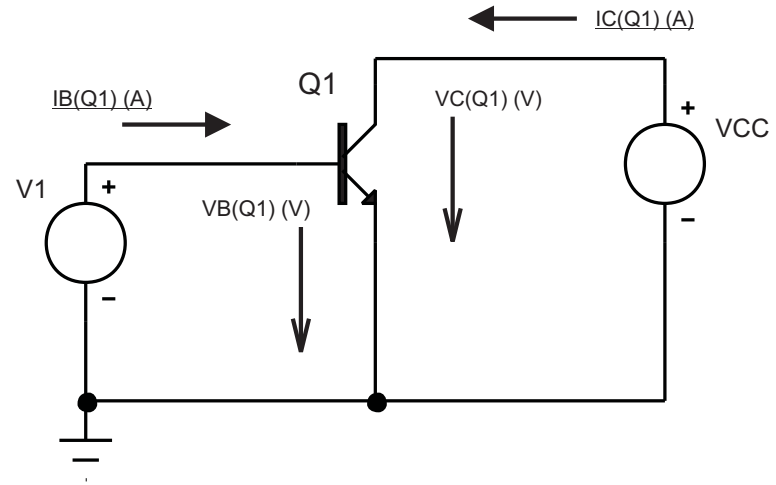


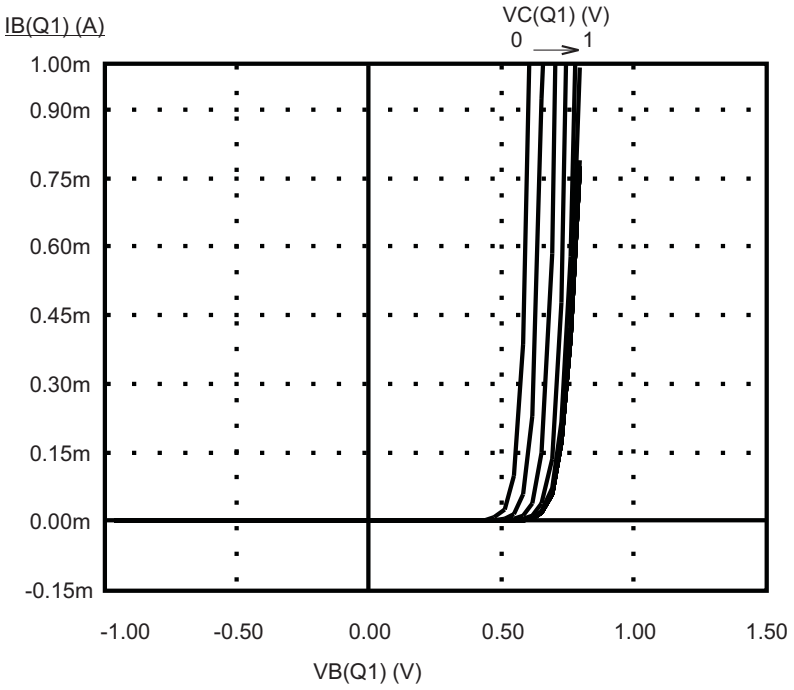
$$i_E = i_B + \beta i_B, \quad i_C = \beta i_B, \quad \beta = \frac{i_C}{i_B}, \quad \frac{i_C}{i_E} = \frac{\beta}{\beta + 1} = \alpha$$

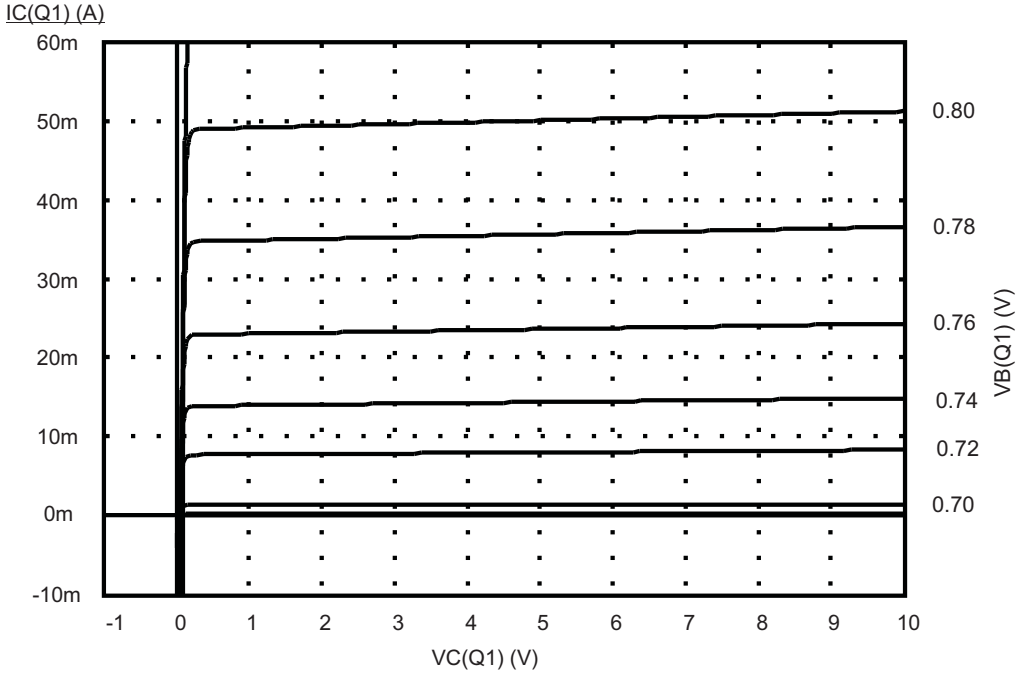
Bipolární tranzistor se společným emitorem jako nelineární dvojbran



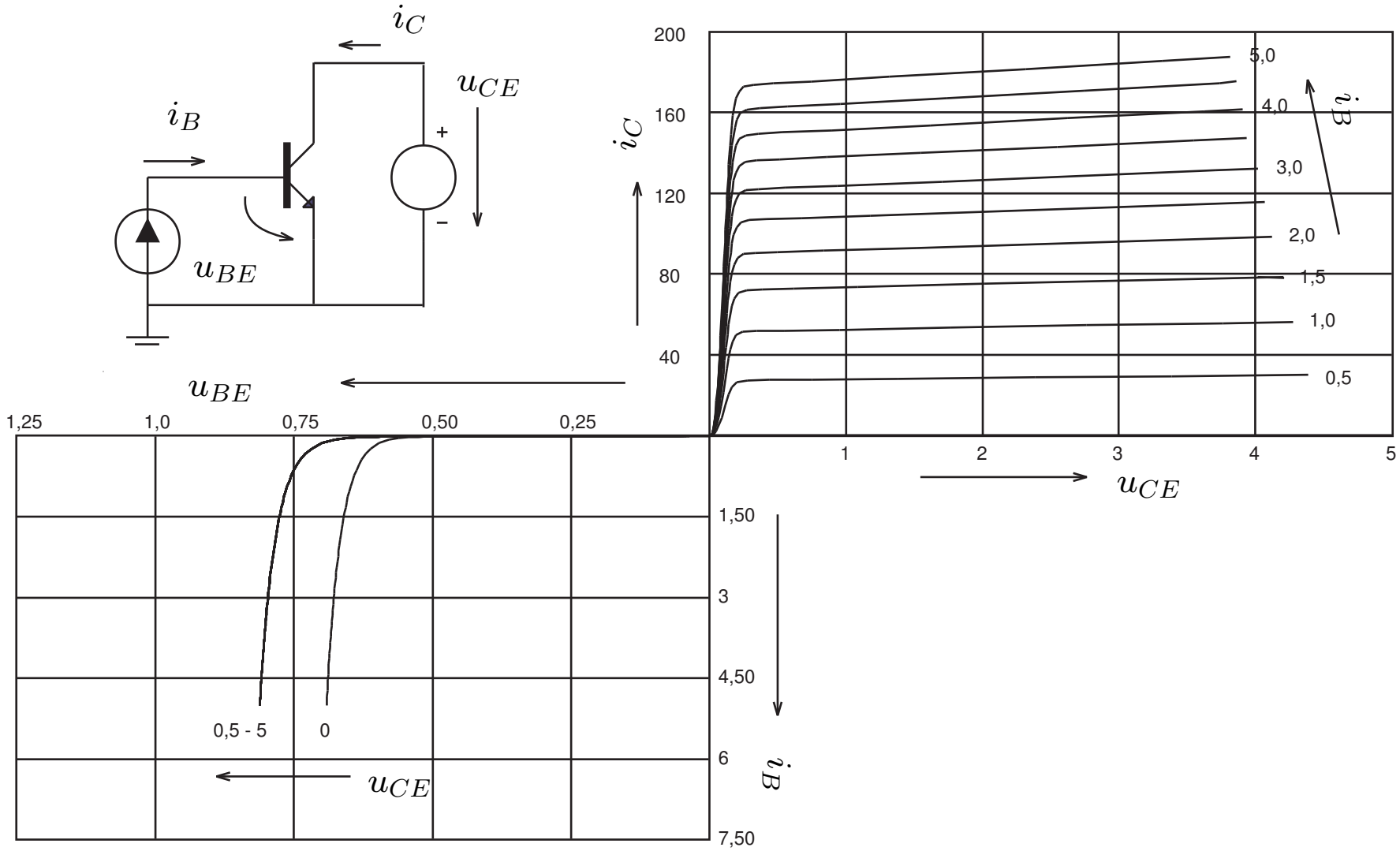
Charakteristiky tranzistoru



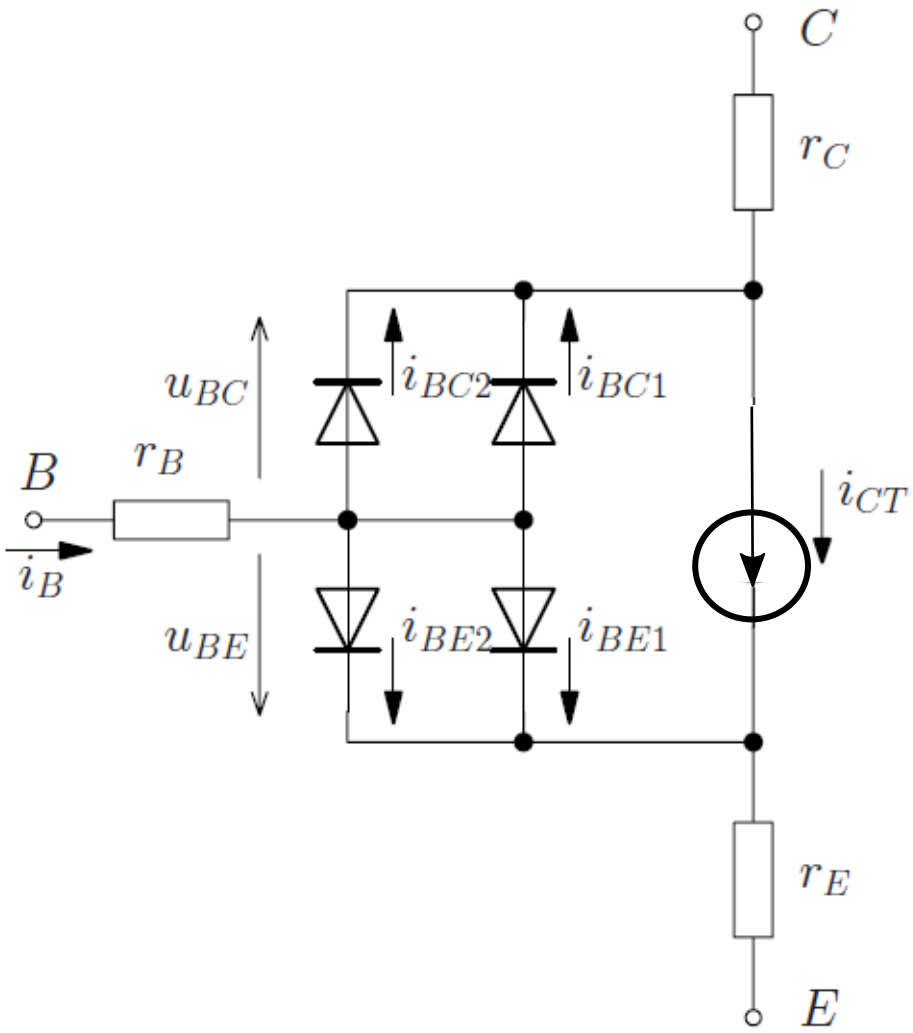




Charakteristiky tranzistoru – obvyklý graf



Gummel-Poonův fyzikální model pro všechny režimy činnosti



Gummel-Poonův model – rovnice

$$i_{BE1} = \frac{I_S\left(e^{\frac{u_{BE}}{U_T}} - 1\right)}{B_F}$$

$$i_{BE2} = I_{SE}\left(e^{\frac{u_{BE}}{n_E U_T}} - 1\right)$$

$$i_{BC1} = \frac{I_S\left(e^{\frac{u_{BC}}{U_T}} - 1\right)}{B_R}$$

$$i_{BC2} = I_{SC}\left(e^{\frac{u_{BC}}{n_C U_T}} - 1\right)$$

$$i_{CT} = \frac{i_{CE} - i_{EC}}{K}$$

$$i_{CE} = I_S\left(e^{\frac{u_{BE}}{U_T}} - 1\right)$$

$$i_{EC} = I_S\left(e^{\frac{u_{BC}}{U_T}} - 1\right)$$

$$K = \frac{1}{1 - \frac{u_{BC}}{V_A}},$$

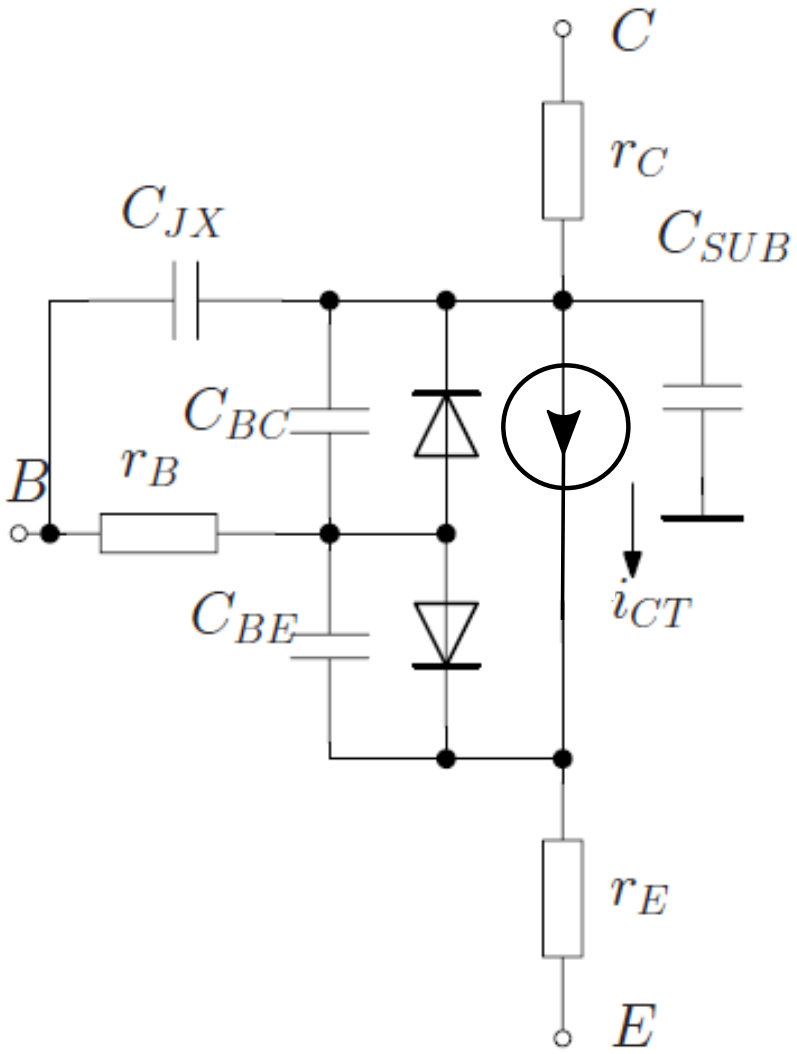
$$B_F = \frac{\alpha_N}{1 - \alpha_N}$$

$$B_R = \frac{\alpha_I}{1 - \alpha_I}$$

$$B_S = \frac{i_C}{i_B} \quad (u_{CB} = 0).$$

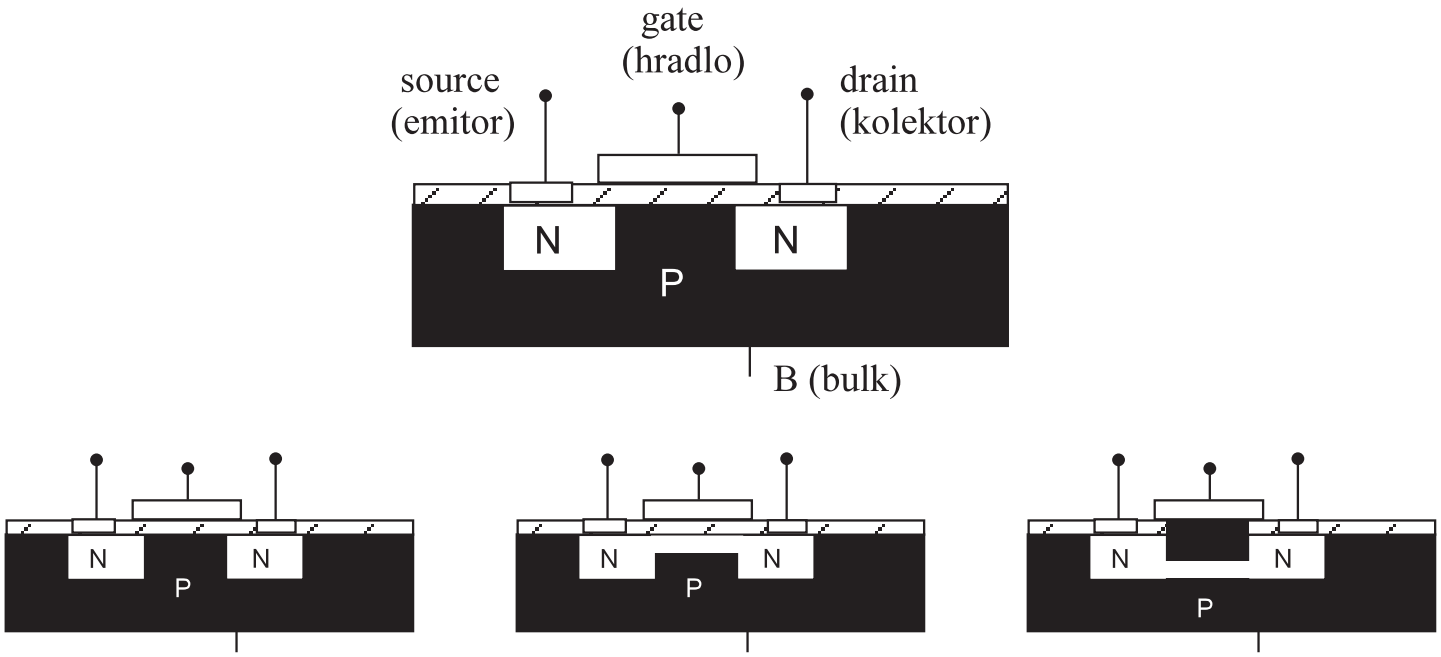
$$\frac{i_C}{i_{Bn}} = B_n < B_S.$$

Gummel-Poonův dynamický model

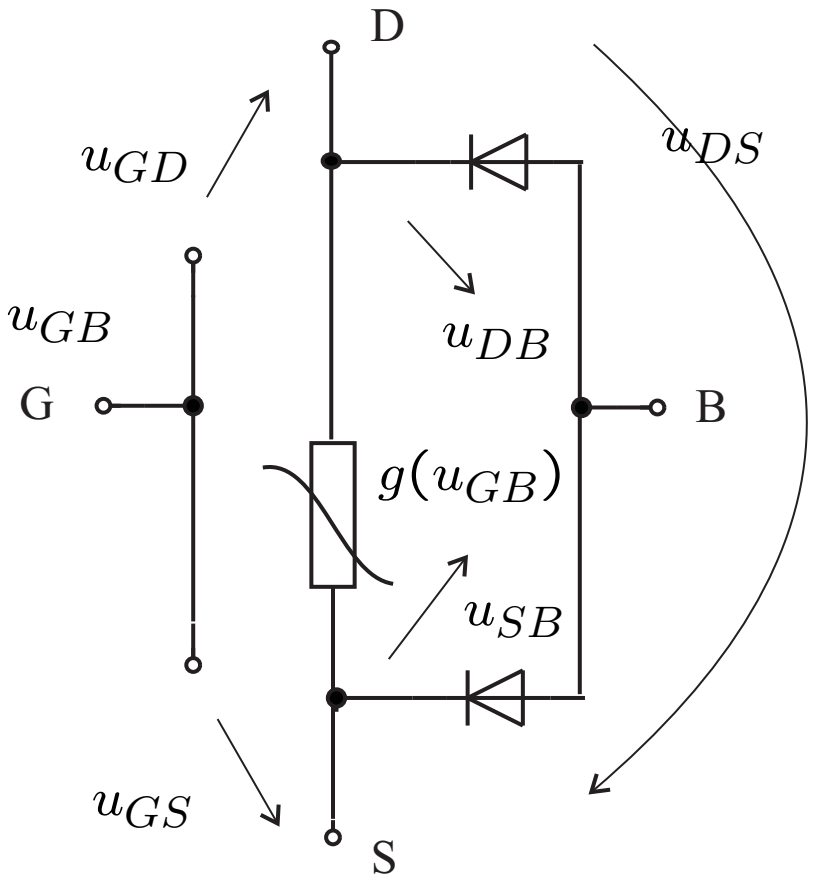


Tranzistor řízený elektrickým polem – unipolární tranzistor

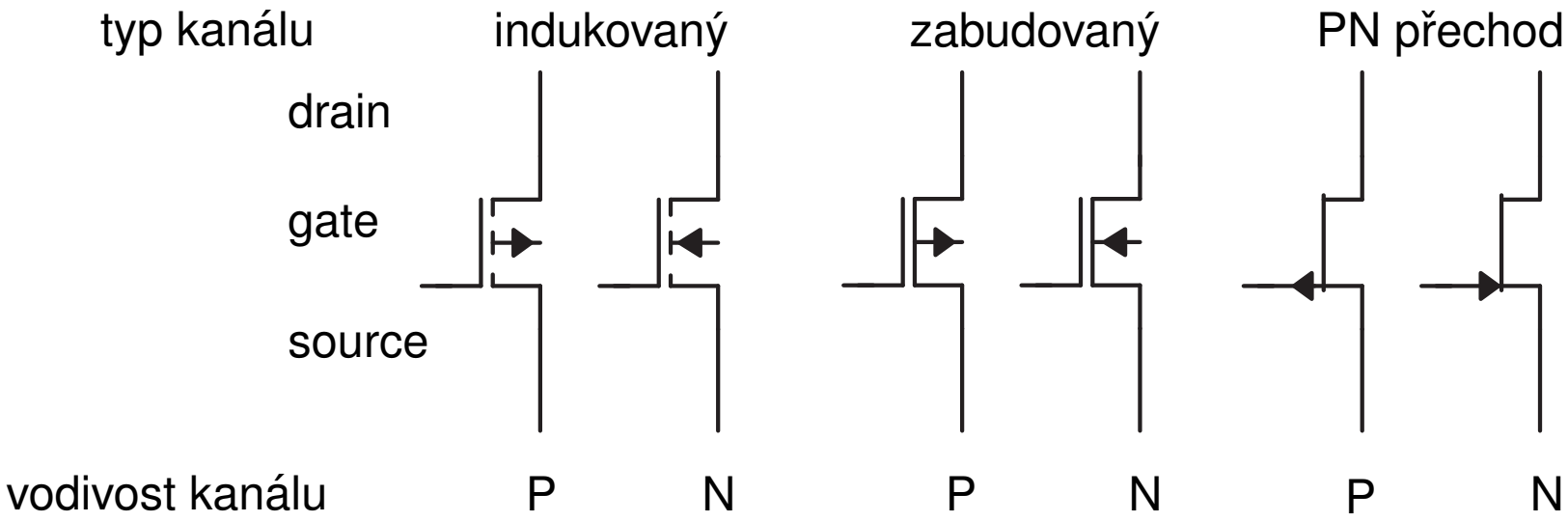
MOS FET



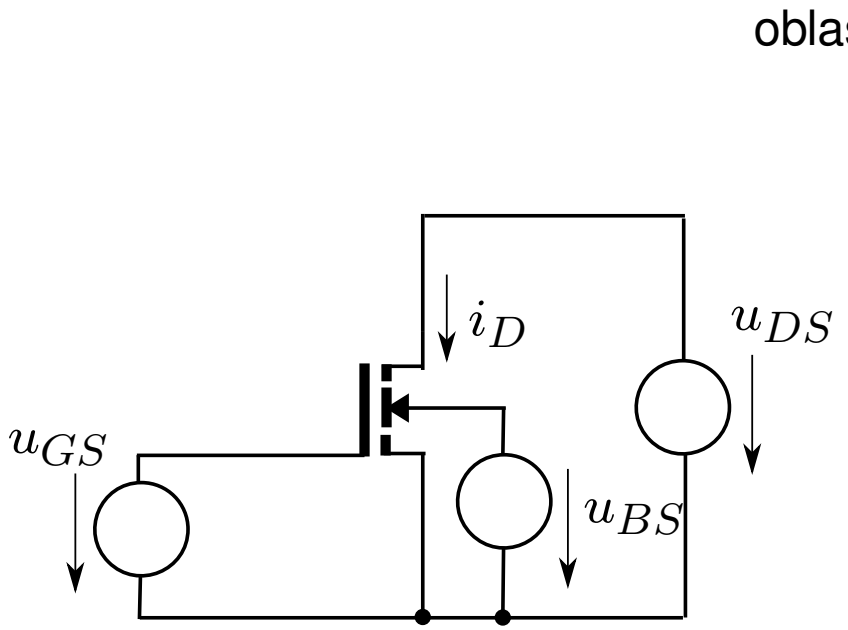
Model unipolárního tranzistoru

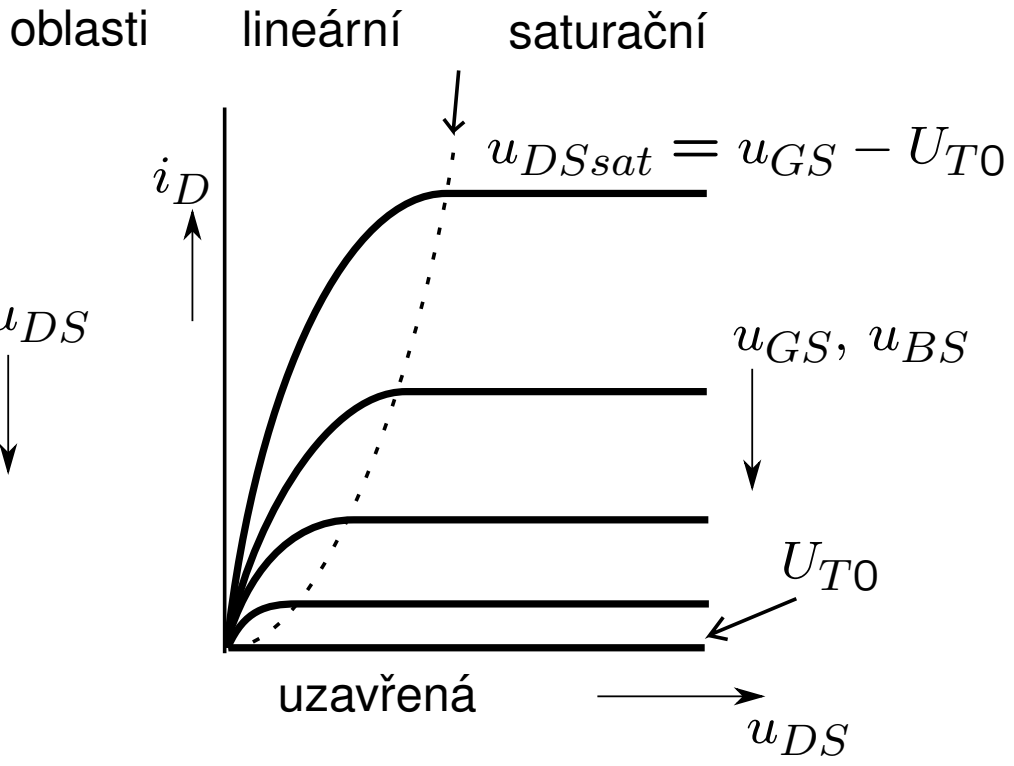


Typy a schematické značky FETů



Charakteristiky FETu





Aproximace charakteristik FETu

Uzavřená oblast

$$i_D = 0 \quad \text{pro} \quad u_{GS} \leq U_{T0}$$

Lineární oblast pro $0 < u_{DS} \leq (u_{GS} - U_{T0})$

$$i_D = \frac{W}{L}\mu_n C_{ox} u_{DS}\left(u_{GS} - U_{T0} - \frac{u_{DS}}{2}\right)$$

kde W je šířka kanálu, L je délka kanálu, μ_n pohyblivost nosičů náboje, C_{ox} je kapacita na jednotku plochy gatu

Saturační oblast pro $u_{DS} > u_{DSsat}$

$$i_D = \frac{W}{2L}\mu_n C_{ox}(u_{GS} - U_{T0})^2\left[1 + \lambda(u_{DS} - u_{DSsat})\right]$$

Dynamický model polem řízeného tranzistoru