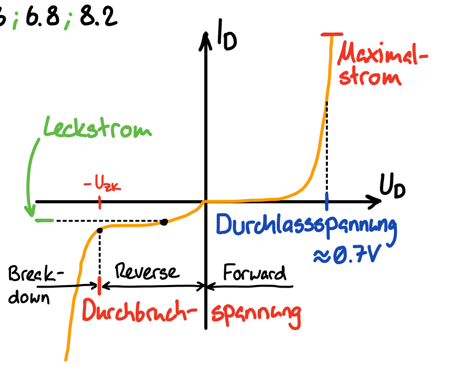
E12-Reihe 1.0; 1.2; 1.5; 1.8; 2.2; 2.7; 3.3; 3.9; 4.7; 5.6; 6.8; 8.2

Diode / Z-Diode

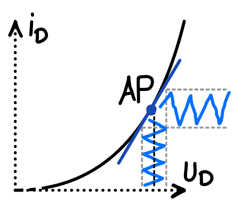
damit $I_D = 0$ bei $U_D = 0$

$$\boxed{I_D = I_{SS} \cdot \left(e^{\frac{U_D}{n U_T}} - 1\right)} \qquad \boxed{U_T = \frac{k_B \cdot T}{q}}$$

($q = 1.6 \cdot 10^{-19}\,As$; $k_B = 1.38 \cdot 10^{-23}\,J/K$;
$T = \vartheta + 273.15\,K$) $U_T(25°) \approx 26\,mV$

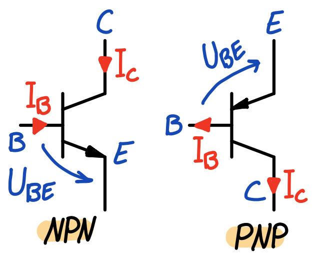


Kleinsignal-Ersatzschaltung



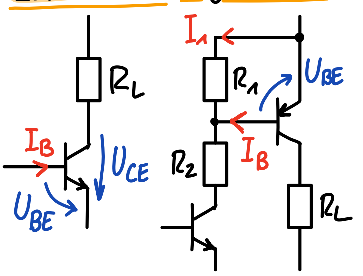
$$\boxed{r_D = \frac{n \cdot U_T}{I_D}}$$

Bipolar Junction Transistor



$$\boxed{I_C = I_B \cdot \frac{B}{ü}} \leftarrow (1 \dots 10)$$

Low-Side High-Side



$$\boxed{I_1 \approx 10\% \cdot I_B}$$

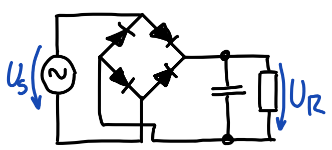
Line Regulation

$$\boxed{\frac{\Delta \text{Ausgang}}{\Delta \text{Eingang}} = \frac{\Delta U_{aus}}{\Delta U_{ein}}}$$

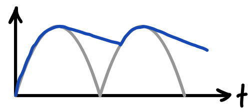
Load Regulation

$$\boxed{\frac{\Delta \text{Ausgang}}{\Delta \text{Belastung}} = \frac{\Delta U_{aus}}{\Delta I_{aus}}}$$

Bsp. Spannungsquelle



$$\boxed{U_R = \hat{U} \cdot \left(1 - e^{-\frac{T}{RC}}\right)}$$



① Cutoff Region ($U_{GS} < U_{th}$)

$$\boxed{I_D = 0}$$

② Triode Region $\begin{pmatrix} U_{GS} \geq U_{th} \\ 0 \leq U_{DS} \leq U_{GS} - U_{th} \end{pmatrix}$

$$\boxed{I_D = k\left(U_{GS} - U_{th} - U_{DS}/2\right) \cdot U_{DS}}$$

③ Steuer. Widerstand ($\frac{U_{GS}}{2} \ll U_{GS} - U_{th}$)

$$\boxed{I_D \approx k(U_{GS} - U_{th}) \cdot U_{DS} = 1/r_{DS}\, U_{DS}}$$

$$\boxed{r_{DS} = \frac{1}{k(U_{GS} - U_{th})} = \frac{1}{g_{fs}}}$$

④ Pinch off ($U_{GS} \geq U_{th}$ & $U_{DS} \geq U_{GS} - U_{th}$)

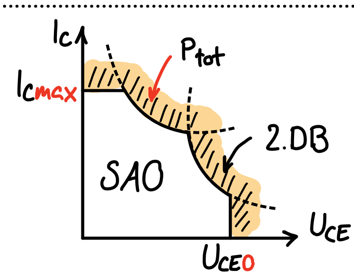
$$\boxed{I_D = \frac{k}{2}(U_{GS} - U_{th})^2 = \frac{g_{fs}}{2}(U_{GS} - U_{th})}$$

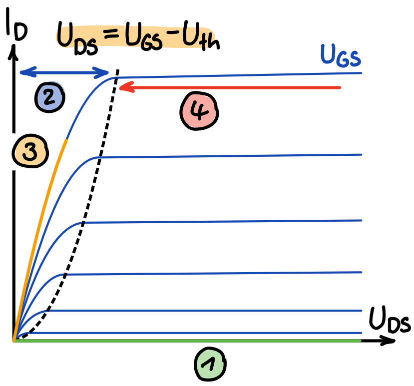
Steilheit am AP → Änderung I_D zu Änderung U_{GS}

$$\boxed{g_{fs} = k(U_{GS} - U_{th}) = \sqrt{2k\, I_{D(AP)}} = \frac{2}{|U_{th}|}\sqrt{I_{D(GS=0)} \cdot I_{D(AP)}}}$$

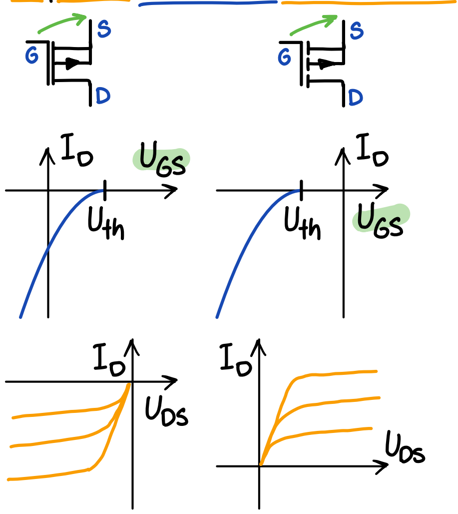
Transkonduktanz- & Steilheitkoeffizient

$$\boxed{k = \frac{g_{fs}}{U_{GS} - U_{th}} = \frac{g_{fs}^2}{2 \cdot I_{D(AP)}} = \frac{2 \cdot I_D(GS=0)}{(U_{GS} - U_{th})^2}}$$

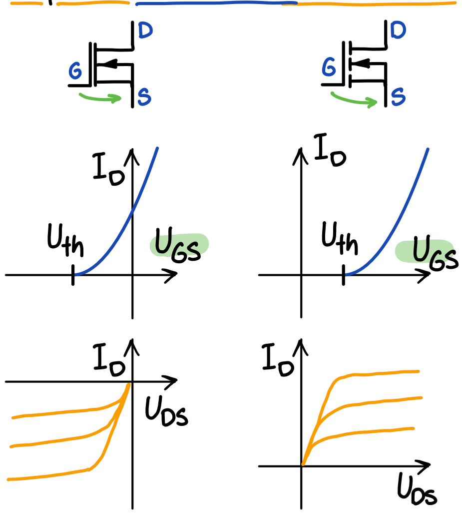




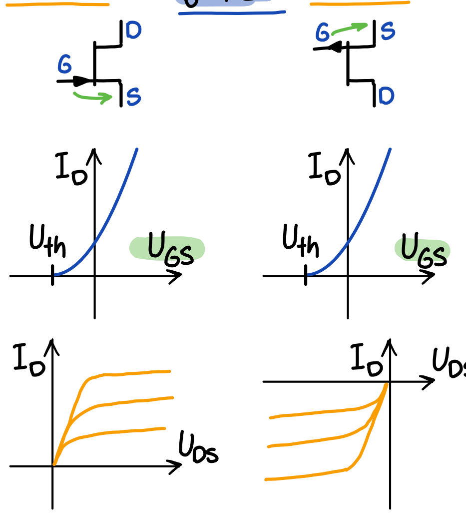
Depletion P-Kanal Enhancement



Depletion N-Kanal Enhancement

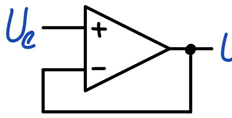


N-Kanal J-FET P-Kanal



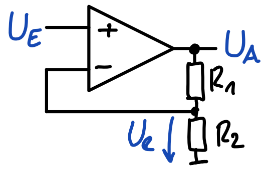
OPV

Impedanzwandler



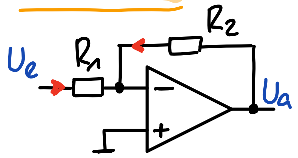
$U_A = U_E$ | $G = 1$

Nichtinvertierend



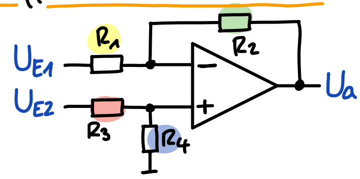
$U_A = U_E\left(1+\frac{R_1}{R_2}\right)$

Invertierend



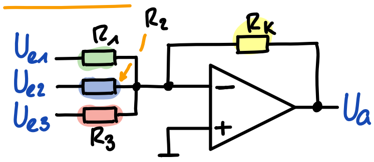
$U_a = U_e\left(-\frac{R_2}{R_1}\right)$

Differenzierer / Subtrahierer



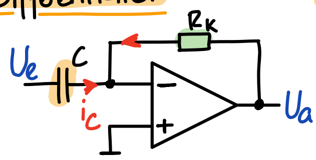
$U_a = U_{E2}\,\frac{R_1+R_2}{R_1}\,\frac{R_4}{R_3+R_4} - U_{E1}\,\frac{R_2}{R_1}$

Addierer



$U_a = -\left(\frac{U_{e1}}{R_1}+\frac{U_{e2}}{R_2}+\frac{U_{e3}}{R_3}\right)R_K$

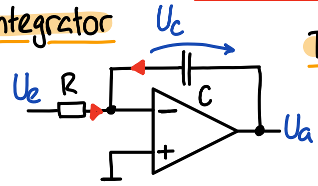
Differentiator



$U_a = -R_K\cdot C\,\frac{dU_e}{dt}$

$G = -\frac{Z_2}{Z_1} = -sRC$

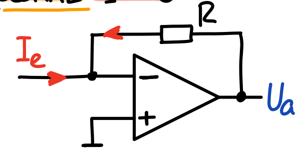
Integrator



$U_A = -\frac{1}{RC}\int U_E\,dt + U_C(0s)$

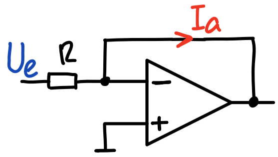
$G = -\frac{1}{sRC}$

Transimpedanz $I \rightarrow U$



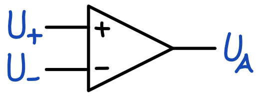
$U_a = -R\cdot I_e$

Transkonduktanz



$I_A = \frac{U_E}{R}$ | $G = \frac{1}{R}$

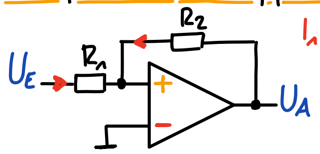
Ideal



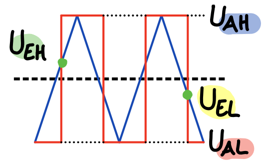
$U_A = (U_+ - U_-)\cdot A$

Komparator / Mitkopplung

$I_1 = -I_2$

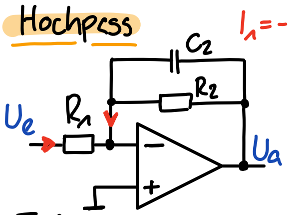


$U_{EHi} = -\frac{R_1}{R_2}\cdot U_{ALo}$ | $U_{ELo} = -\frac{R_1}{R_2}\cdot U_{AHi}$



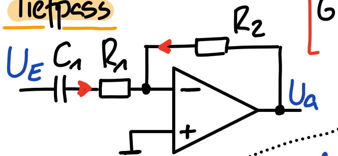
Hochpass

$I_1 = -I_2$



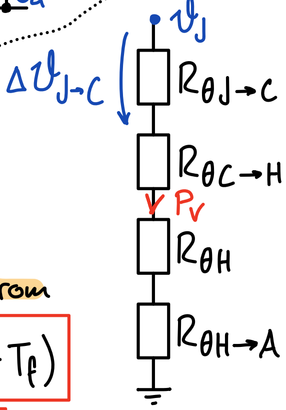
$G(s) = -\frac{R_2}{R_1\,(C_2\cdot R_2\cdot s+1)}$

Tiefpass



$G(s) = -\frac{C_1\cdot R_2\cdot s}{C_1\cdot R_1\cdot s+1}$

Wärmeleitung

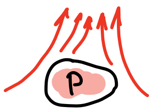


$P_V = \frac{\Delta\vartheta}{R_{th}}$ $\left[\frac{K}{W}\right]$

Konvektiver Wärmestrom

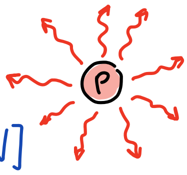
$\dot{Q}_{conv} = h\cdot A\,(T_S - T_f)$

$\rightarrow R_{thconv} = \frac{1}{hA}$



h Wärmetransferkoeff. $\left[\frac{W}{m^2K}\right]$

Wärmestrahlung



$P = \varepsilon\sigma A\,(T_{Body}^4 - T_{Amb}^4)$ [W]

ε Emmisionskoeff. (schwarz = 1)

σ Proportionalitätskonst $\left(5.67\cdot 10^{-8}\,\frac{W}{m^2K^4}\right)$

$T_{B,A}$ absolute Temperaturen

Bode Diagramm

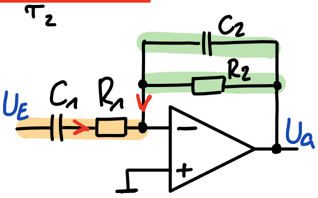
$\left(G_{dB} = 20\cdot\log(|G|)\ /\ |G| = 10^{\frac{G_{dB}}{20}}\right)$

① Übertragungsfunktion → τ bestimmen

$G(s) = \frac{U_A}{U_E} = -\frac{Z_2}{Z_1} = -\frac{R_2\|X_2}{R_1+X_1} = \frac{-C_1 R_2\cdot s}{\underbrace{(C_2\cdot R_2\cdot s+1)}_{\tau_1}\underbrace{(C_1\cdot R_1\cdot s+1)}_{\tau_2}}$

② DC-Verstärkung ($f = 0$) (wegen inv. OPV)

$G_{DC} = -\frac{R_2}{R_1} = -2 \mathrel{\hat{=}} 6dB\ \&\ \varphi = -180°$



③ Analyse $\omega \rightarrow 0$ & $\omega \rightarrow \infty$

$\lim_{s\to 0} G(s) = 0$ | $\lim_{s\to\infty} G(s) = 0$

$C_1 = 1\mu F$ $C_2 = 1nF$
$R_1 = 2k\Omega$ $R_2 = 1k\Omega$

④ Grenzfrequenzen berechnen

TI-nspire (solve(|imag(G)| = |real(G)|, w)) ! $s \rightarrow \omega\cdot j$

$\omega_{Gu} = (R_1\cdot C_1)^{-1} = 500k\,\frac{rad}{s}$; $\omega_{Go} = (R_2\cdot C_2)^{-1} = 1\ \frac{rad}{s}$

⑤ Winkel berechnen

$\varphi_{Gu} = \arctan(\cdots) + \varphi_{OPV}$ | $\varphi_{Go} = angle(G(\omega_{Go})) + \varphi_{OPV}$

$\rightarrow \varphi_{Gu} = -135°$ | $\rightarrow \varphi_{Go} = -225°$