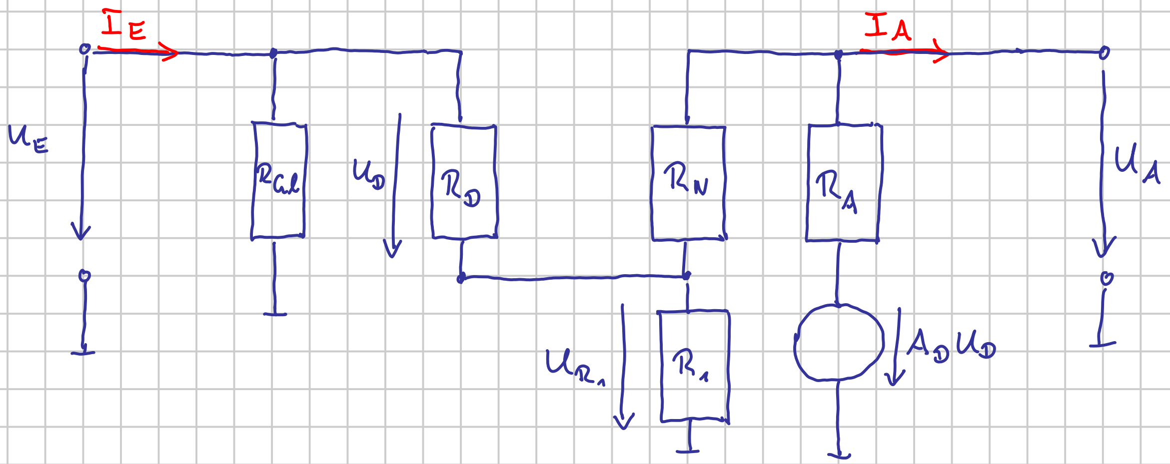
## nicht-invertierender OpV: Kleinsignal-Eingangswiderstand




Eingangsstrom: $I_E = \dfrac{U_E}{R_{Gl}} + \dfrac{U_D}{R_D}$ ← Differenzsignal-Widerstand

Gleichtaktsignal-Widerstand

Vereinfachungen: $R_{Gl} \gg R_1$, $R_A \ll R_N$, $R_A \ll R_1$, $I_{R_{Gl}} \ll I_{R_1}$

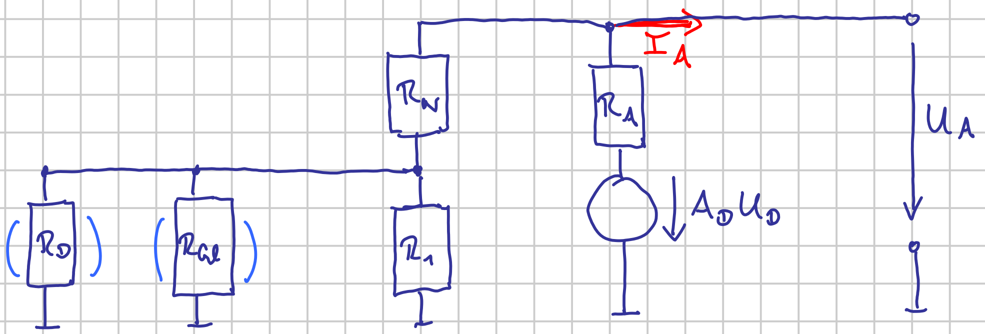
Differenzspannung: $U_D = U_E - U_{R_1} \approx U_E - \dfrac{R_1}{R_1 + R_N} A_D U_D$

$$\Leftrightarrow \quad U_D = \frac{U_E}{1 + \underbrace{\frac{R_1}{R_1+R_N} A_D}_{g \,=\, k A_D \,\gg\, 1}}$$

$$\Rightarrow \quad I_E = \frac{U_E}{R_{Gl}} + \frac{U_E}{g R_D} = U_E \left( \frac{1}{R_{Gl}} + \frac{1}{g R_D} \right)$$

$$\Rightarrow \quad r_E = \frac{dU_E}{dI_E} = \frac{1}{\frac{1}{R_{Gl}} + \frac{1}{g R_D}} \approx R_{Gl}$$

## nicht-invertierender OpV: Kleinsignal-Ausgangswiderstand




$R_D \gg R_1$, $R_{Gl} \gg R_1$

$$\Rightarrow U_D = -U_A \underbrace{\frac{R_1}{R_1+R_N}}_{k} = -U_A k$$ Differenz-Eingangsspannung

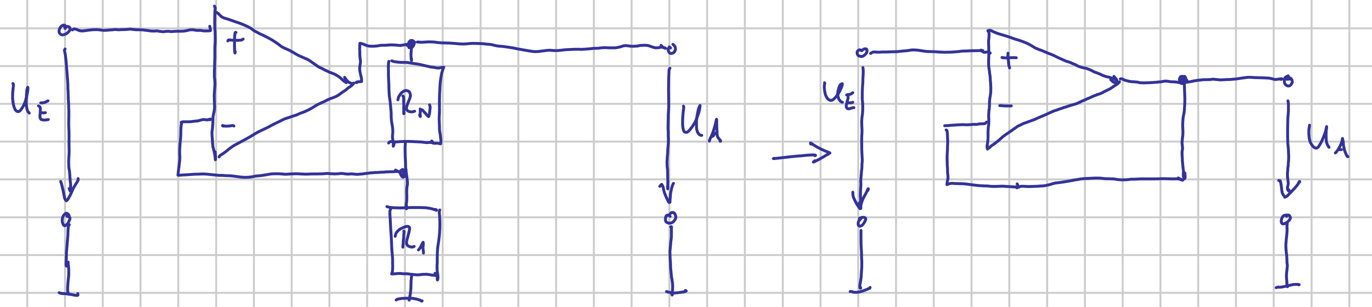
Ausgangsstrom: $$I_A = \frac{A_D U_D - U_A}{R_A} - \frac{U_A}{R_1+R_N} = \frac{(A_D U_D - U_A)(R_1+R_N) - U_A R_A}{R_A(R_1+R_N)}$$

$$= U_A \left( \frac{-A_D k - 1}{R_1} - \frac{1}{R_1+R_N} \right)$$

$$= U_A \left( \frac{(-A_D k - 1)(R_1+R_N) - R_A}{R_A(R_1+R_N)} \right) \approx U_A \frac{-A_D R_1}{R_A(R_1+R_N)}$$

Kleinsignal-Ausgangswiderstand: $$r_A = \frac{dU_A}{dI_A} = \underbrace{\frac{R_1+R_N}{R_1}}_{1/k} \frac{R_A}{A_D} = \frac{R_A}{k A_D} = \frac{R_A}{g} \ll R_A$$

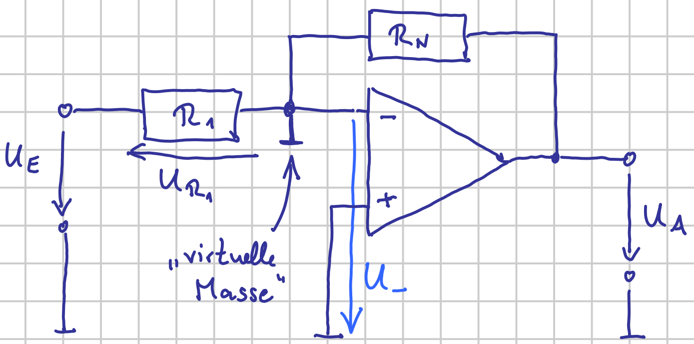
Spannungsfolger: nicht-invertierender OpV mit Gegenkopplung, $V = 1$




$$V = \frac{R_1+R_N}{R_1} = 1 + \frac{R_N}{R_1} \approx 1, \text{ wenn } R_N \to 0 \text{ und } R_1 \to \infty$$

Ausgangs-Kleinsignalwiderstand: $$r_A = \underbrace{\frac{R_1+R_N}{R_1}}_{=1} \frac{R_A}{A_D} = \frac{R_A}{A_D} \ll R_A$$

Realer invertierender OpV

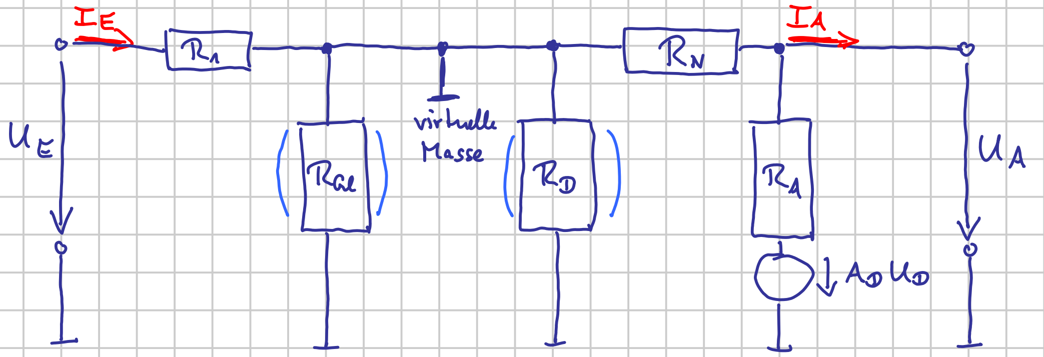



ideale OpV: $$U_- = \underbrace{(U_A - U_E)\frac{R_1}{R_1+R_N}}_{U_{R_1}} + U_E \approx 0$$

Knotenregel: $$\frac{U_E}{R_1} + \frac{U_A}{R_N} = 0$$

$$\Leftrightarrow V = \frac{U_A}{U_E} = -\frac{R_N}{R_1}$$

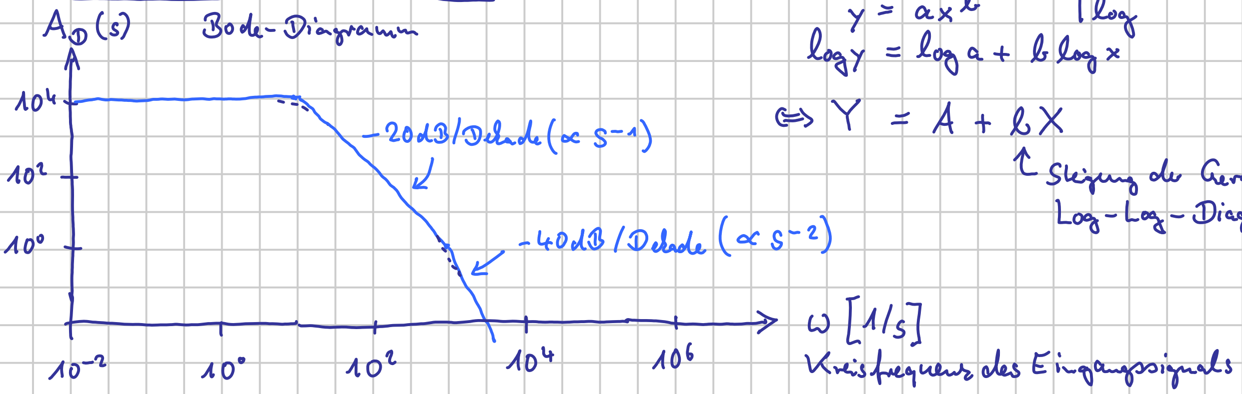
## Kleinsignal-Ausgangswiderstand des realen invertierenden OpV:




$R_{Gl} \gg R_A$
$R_D \gg R_A$

$$r_A = -\frac{dU_A}{dI_A} = \frac{(R_1 + R_N) R_A}{R_1 A_D} = \frac{R_A}{k A_D} = \frac{R_A}{g} \ll R_A$$

## Übertragungsverhalten des OpV




$$y = a x^b \quad | \log$$
$$\log y = \log a + b \log x$$
$$\Leftrightarrow Y = A + bX$$

$b$: Steigung der Geraden im Log-Log-Diagramm

OpV-Schaltung: endliche frequenzabhängige Verstärkung $A_D(s) = H(s)$

$$A_D(s) = K \frac{\prod_{\mu=1}^{m} (s - s_{0\mu})}{\prod_{\nu=1}^{n} (s - s_{\infty\nu})}$$

Nullstellen im Zähler $\hat{=}$ Nullstellen der Übertragungsfunktion

Nullstellen im Nenner $\hat{=}$ Polstellen der Übertragungsfunktion

Nennerpolynom: $D(s) = \prod_{\nu=1}^{n} (s - s_{\infty\nu})$, Zählerpolynom = const

Die Werte der $s_{\infty\nu}$ haben sehr stark unterschiedliche Größenordnungen.

z.B. $s_{\infty 1} = 10\, s^{-1}$, $s_{\infty 2} = 1000\, s^{-1}$

$0 \leq s \leq s_{\infty 1}$ : $D(s)$ ist praktisch konstant, $(s - s_{\infty 1}) \approx$ const
$(s - s_{\infty 2}) \approx$ const

$s_{\infty 1} \ll s \ll s_{\infty 2}$ : $(s - s_{\infty 1}) \approx s$, $(s - s_{\infty 2}) \approx$ const

$$\Rightarrow D(s) \propto s, \quad H(s) \propto \frac{1}{s}$$

$s_{\infty 2} \ll s$ : $(s - s_{\infty 1}) \approx s$, $(s - s_{\infty 2}) \approx s \Rightarrow D(s) \propto s^2$, $H(s) \propto \frac{1}{s^2}$