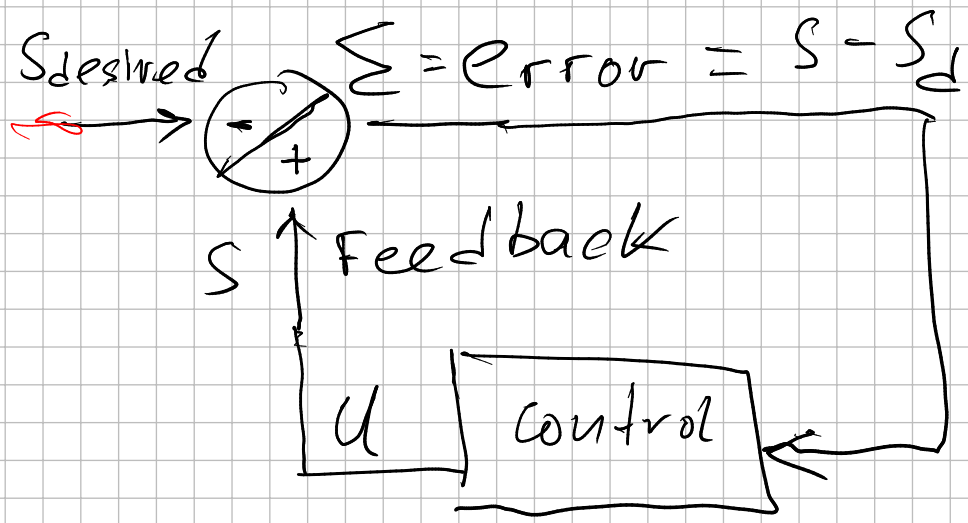
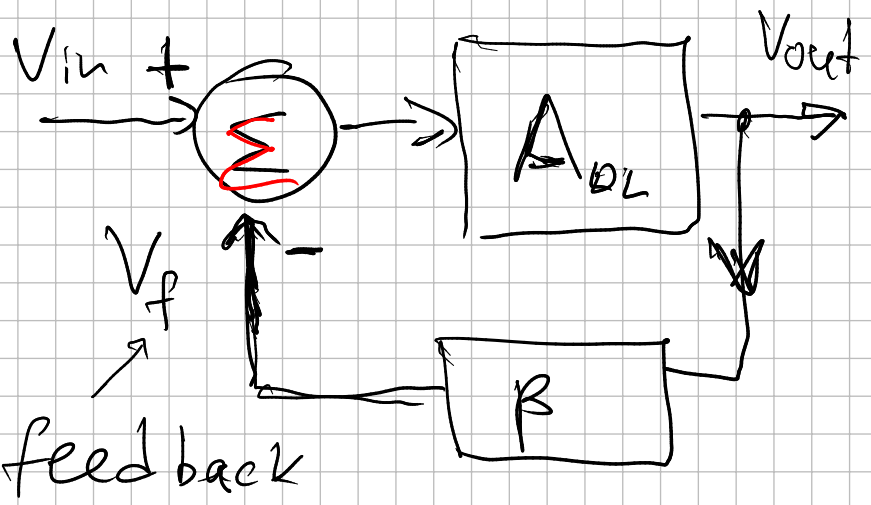
Feedback

Previous view



Electrical engineers notation



$V_f = \beta \cdot V_{out}$

β - feedback gain

A - open loop gain

$$V_{out} = (V_{in} - V_f) \cdot A_{OL}$$

V_f → $\beta \cdot V_{out}$

$$V_{out} = (V_{in} - \beta V_{out}) \cdot A_{OL}$$

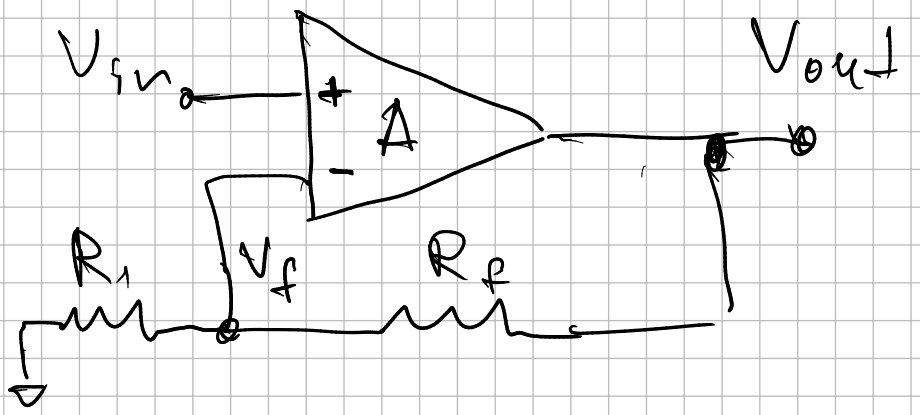
$$\frac{V_{out}}{V_{in}} = \frac{A_{OL}}{1 + \beta A_{OL}} = G = A_{CL}$$

A_{CL}: close loop

$\beta A_{OL} < 0$, positive gain

$\beta \cdot A_{OL} > 0$, negative feedback

$\beta \cdot A_{OL} = -1$ Danger point

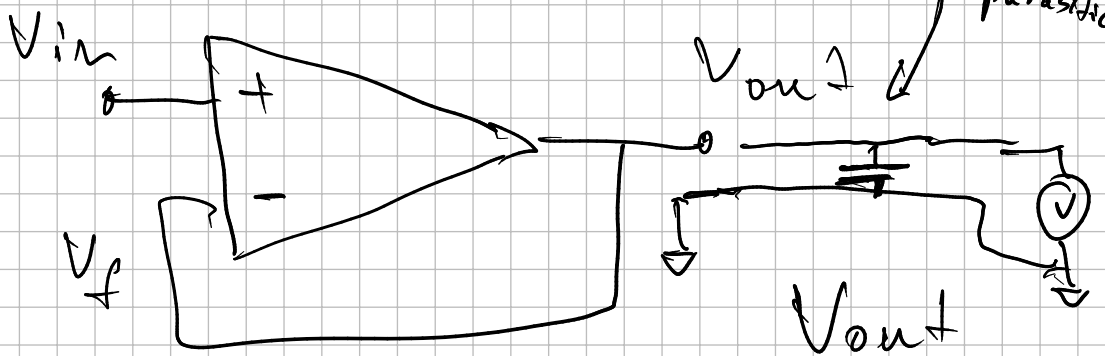


$$V_{out} = \frac{A}{1 + \beta A} \cdot V_{in}$$

$$V_f = V_{out} \cdot \underbrace{\frac{R_1}{R_1 + R_f}}_{= \beta}$$

$$\frac{V_{out}}{V_{in}} = \frac{A}{1 + \frac{R_1}{R_1 + R_f} \cdot A} \xrightarrow{A \to \infty} \frac{A}{\beta \cdot A} = \frac{1}{\beta} = \frac{R_1 + R_f}{R_1}$$

Buffers



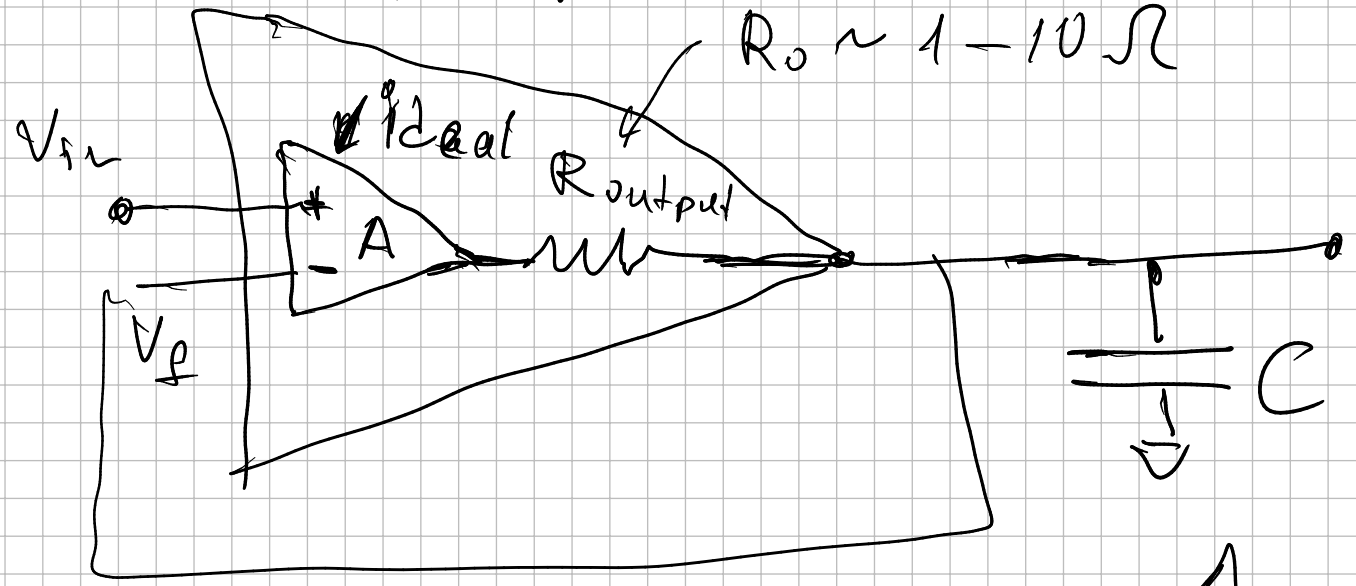
$V_f = \beta \cdot V_{out}$

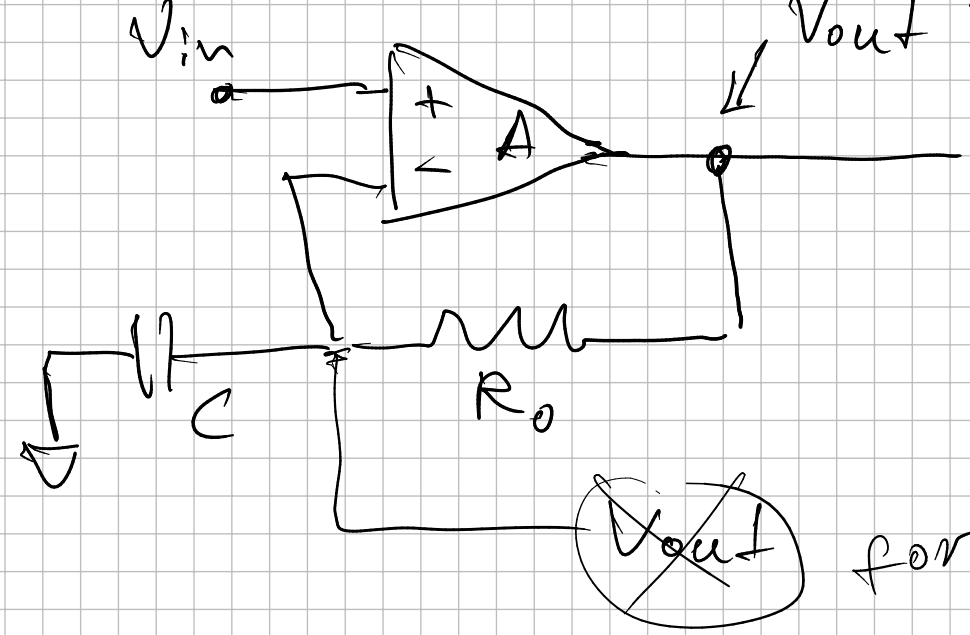
$\beta = 1$

$$\frac{V_{out}}{V_{in}} = \frac{A}{1+\beta A} = \frac{A}{1+A} \xrightarrow[A \to \infty]{} 1$$

$V_{in}(t) \rightarrow$

Real Op Amps have output resistance





$$V_{out} = \frac{A}{1+\beta A} \cdot V_{in}$$

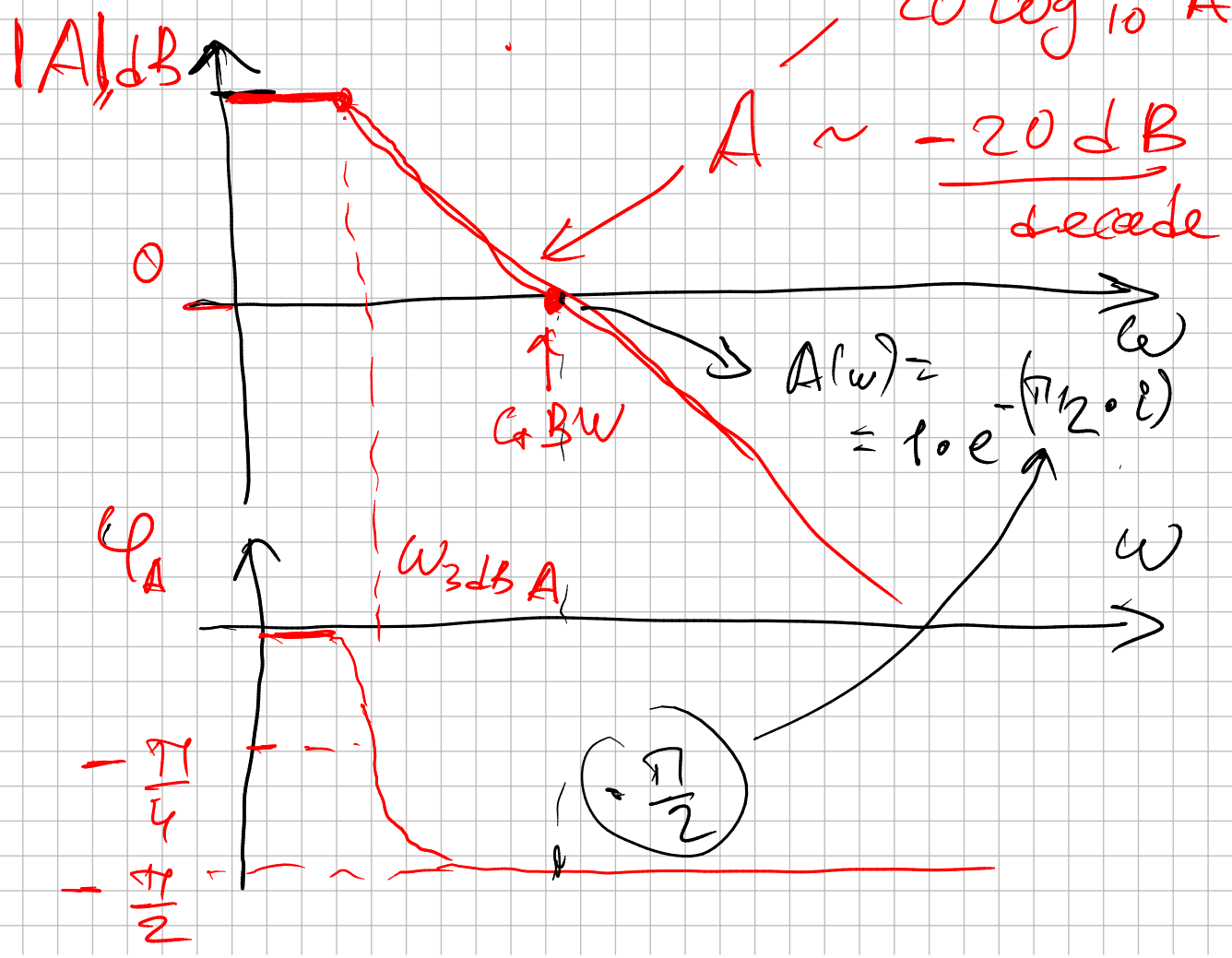
$$\beta = \frac{Z_c}{R_o + Z_c} = \frac{1}{1 + i\frac{\omega}{\omega_{3dB}}}$$

V_{out} for the circuit.

Stability condition

$\beta \cdot A > 1 \iff$ negative feedback

$\beta \cdot A \neq -1$



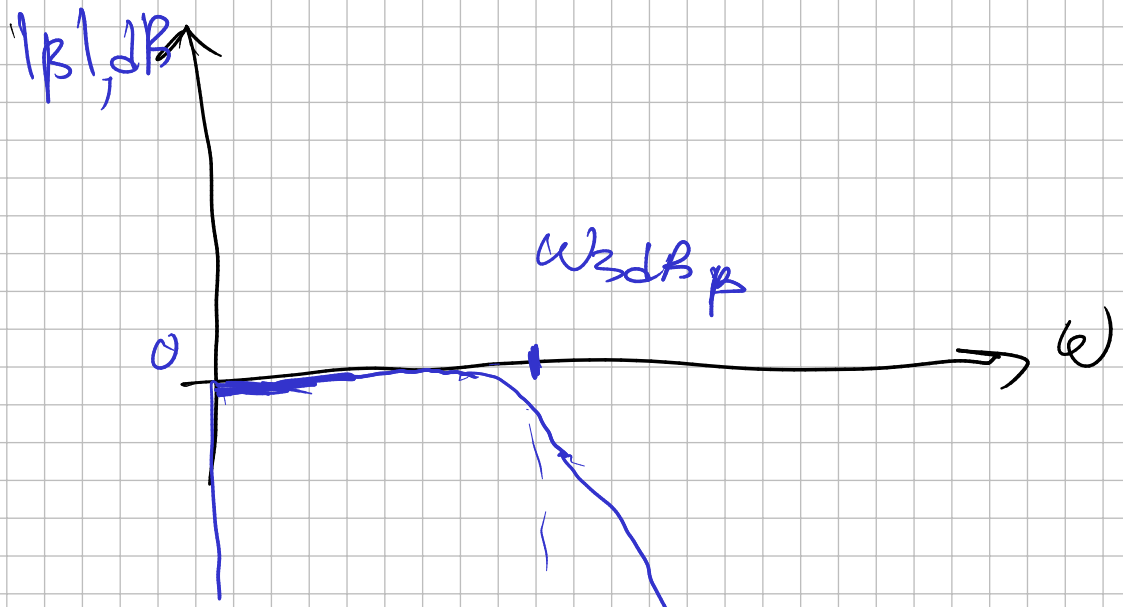
$20 \log_{10} \cdot 1 = 0$

if $\beta(\omega) = 1$

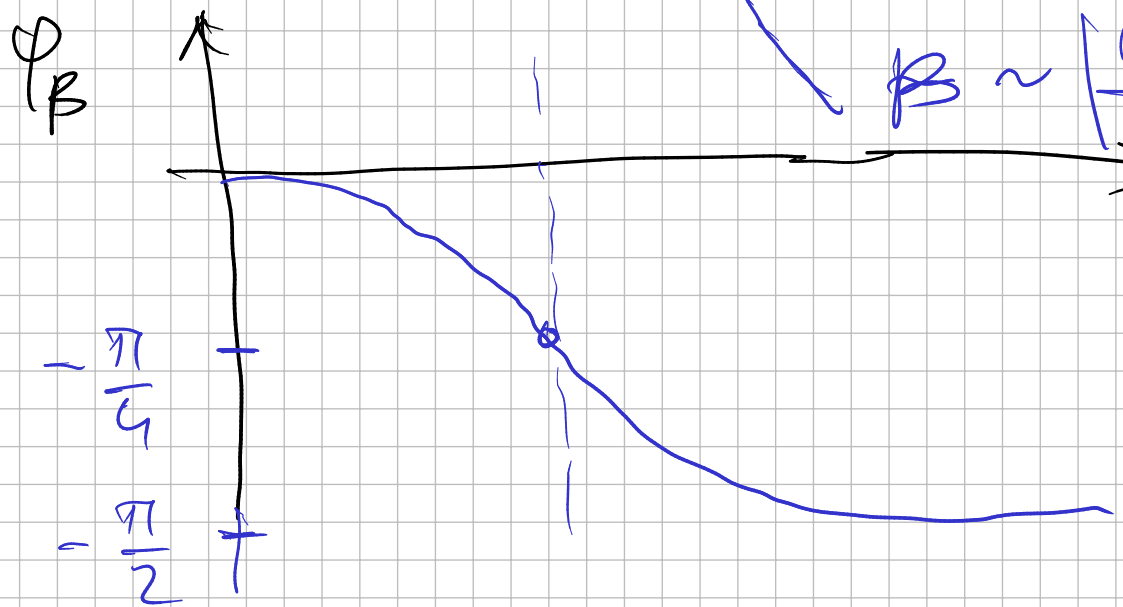
$e^{i\pi} = -1$

φ of danger is π

β - consideration



$\sim \frac{20\ dB}{decade}$



$\beta \sim \left|\frac{\omega_{3dB}}{\omega}\right| \cdot e^{-\frac{\pi}{2} i}$

$\frac{1}{i} = e^{-\frac{\pi}{2} i}$

$$\beta \cdot A \neq -1$$

$$A \neq \ominus \frac{1}{\beta}$$

$\omega \to \infty$

$$20 \log_{10}\left(|A| = \left|\frac{1}{\beta}\right|\right)$$

$$|A|_{dB} = -|\beta|_{dB}$$

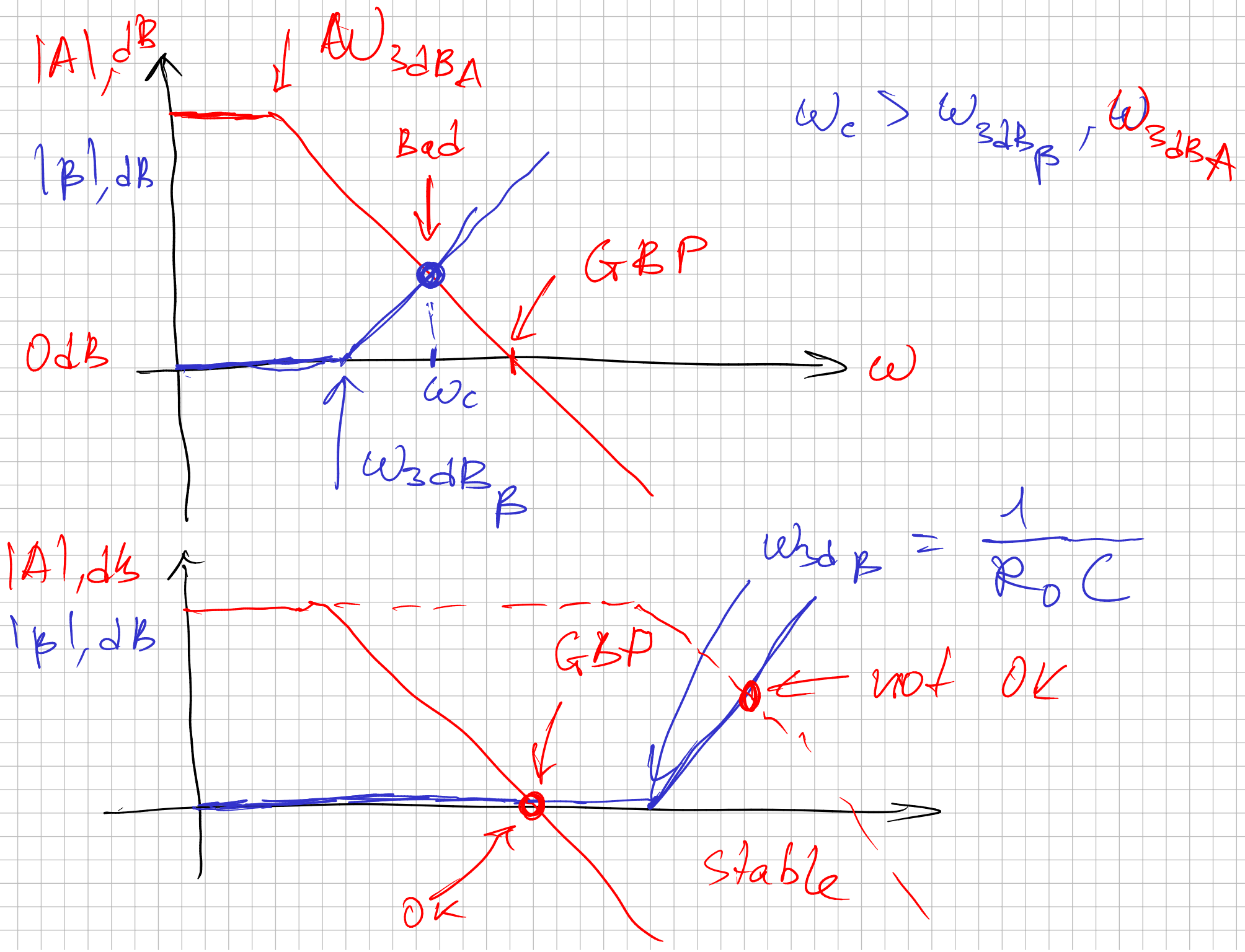
$\omega \to \infty$

$$\beta \sim \frac{\omega_{3dB_\beta}}{\omega} \cdot e^{-i\frac{\pi}{2}}$$

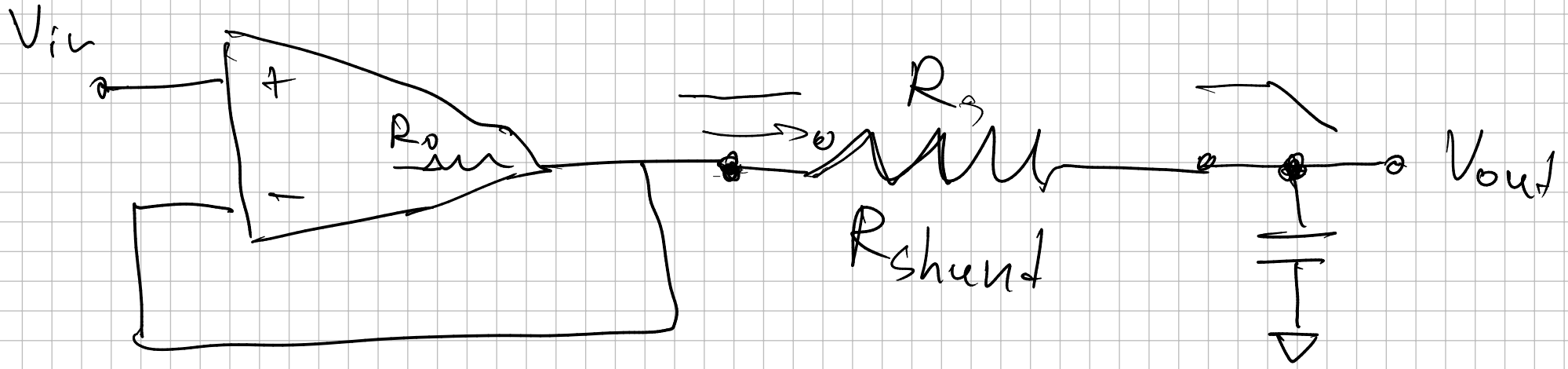
$\times$

$$A \sim \frac{\omega_{3dB_A}}{\omega} e^{-i\frac{\pi}{2}}$$

$$\beta A \sim \frac{\omega_{3dB} \cdot \omega_{3dB_A}}{\omega^2} \; e^{-\pi i} = -1$$


|A|, dB
ω_{3dB_A}
|β|, dB
Bad
GBP
0dB
ω
ω_c
ω_{3dB_β}
$\omega_c > \omega_{3dB_\beta}, \omega_{3dB_A}$
|A|, dB
|β|, dB
$\omega_{3dB} = \frac{1}{R_0 C}$
GBP
not OK
OK
stable

How to stabilize



Price to pay

$$GBW \Rightarrow BW = \frac{1}{R_s \cdot C}$$

$$Z_{out} = R_s + R_o$$