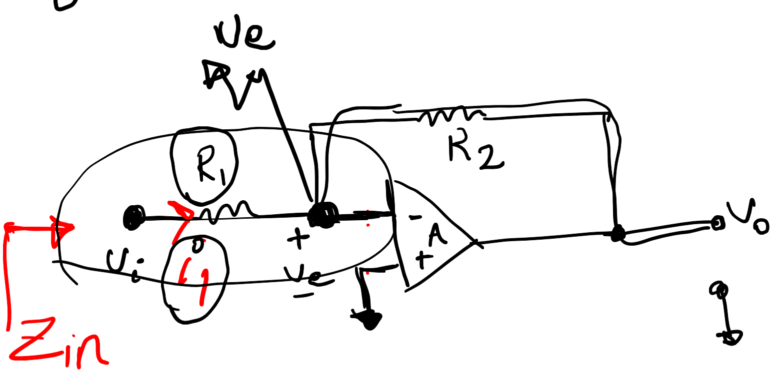
< inverting amplifier input impedance>



$v_e = v^+ - v^- \nearrow 0$

$$v_i = Z_{in}\, i_1$$

① $\boxed{A \to \infty}$ and $f = \dfrac{R_1}{R_1+R_2} \neq 0 \Rightarrow Af \to \infty$

$L(s) \to \infty$

" virtual short "

$v^+ = 0$

$v_e \approx 0$

$$i_1 = \frac{v_i - 0}{R_1}$$

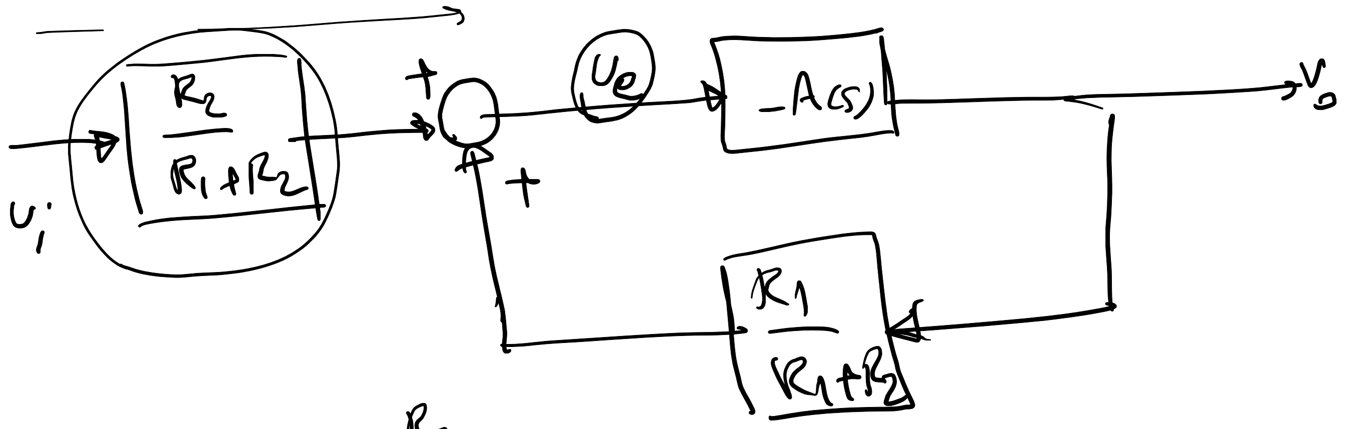
$\Rightarrow Z_{in} = R_1$

② $A = A(s)$

$$\frac{v_i - v_e}{R_1} = i_1$$

$v_i = Z_{in}\, i_1$

$$v_e = \frac{R_2}{R_1+R_2} v_i + \frac{R_1}{R_1+R_2} v_o$$



$$\frac{v_e}{v_i} = \frac{\frac{R_2}{R_1+R_2}}{1 + L(s)}$$

Black's formula

$$i_1 = \frac{1}{R_1}\left(v_i - \boxed{v_e}\right)$$

$$= \frac{1}{R_1}\left(v_i - \frac{R_2/R_1+R_2}{1+L(s)}\,v_i\right)$$

$$i_1 = \underbrace{\frac{1}{R_1}\left(1 - \frac{\frac{R_2}{R_1+R_2}}{1+L(s)}\right)}_{\text{admittance } \quad Y(s)} v_i$$

$$\begin{cases} I = Y\,V \\ V = Z\,I \end{cases}$$

$$Y(s) = \frac{1}{Z(s)}$$

$$Y(s) = \frac{1}{R_1}\left(\frac{1+L(s) - \frac{R_2}{R_1+R_2}}{1+L(s)}\right)$$

$$= \frac{1}{R_1}\left(\frac{\frac{R_1}{R_1+R_2} + L(s)}{1+L(s)}\right)$$

$$Y(s) = \frac{1}{R_1}\left(\frac{f + L(s)}{1 + L(s)}\right)$$

$$L \quad \frac{1}{Y(s)} = \boxed{Z(s) = R_1\left(\frac{1 + L(s)}{f + L(s)}\right)}$$

$L(s) = A(s) f$

$R_1, R_2, A(s)$

① $A \to \infty \rightsquigarrow L \to \infty \Rightarrow Z(s) = R_1$

② $A = A(s) \Rightarrow Z(s) = R_1\left(\frac{\cancel{1 + L(s)}}{\cancel{f + L(s)}}\right)$

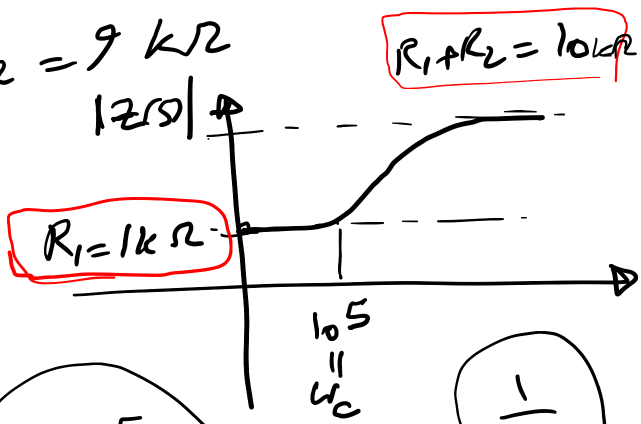
③ $L \to 0$ $\quad Z(s) = R_1/f = \boxed{R_1 + R_2}$

at high frequencies

$\omega \gg \omega_c$

$A(s) = \frac{10^6}{s}$, $R_1 = 1\,k\Omega$, $R_2 = 9\,k\Omega$

$f = \frac{1}{10}$

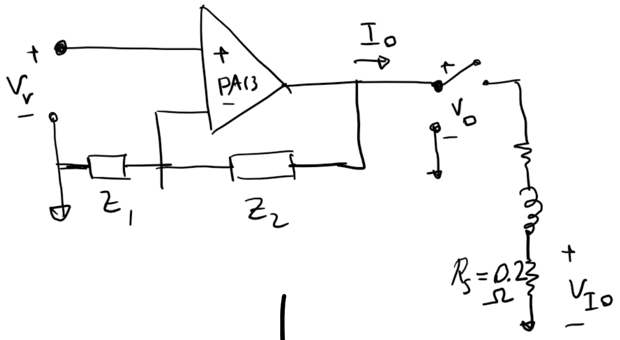


$L(s) = A(s) \times f = \frac{10^5}{s}$

$$Z(s) = 1\left(\frac{1 + \frac{10^5}{s}}{\frac{1}{10} + \frac{10^5}{s}}\right) = \frac{s + 10^5}{0.1s + 10^5}$$

$\frac{1}{0.1}$

< Non_inverting >



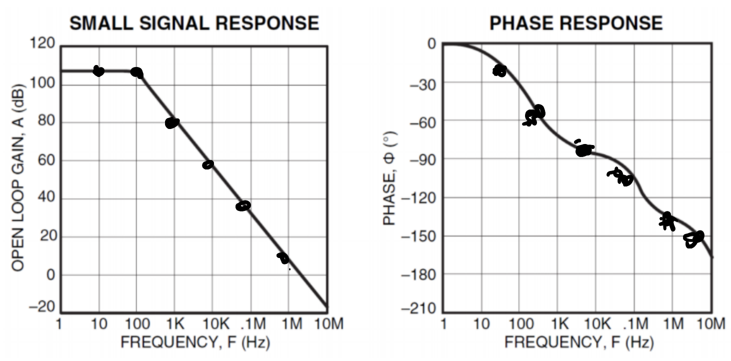


Figure 3: Open-loop frequency response of PA13.

$A(s) = \dfrac{\omega}{s}$

$L(s)$

$T(s) \rightarrow$ complementary

$$f = \frac{Z_1}{Z_1 + Z_2}$$

$$G(s) = \frac{A(s)}{1 + A(s)f}$$

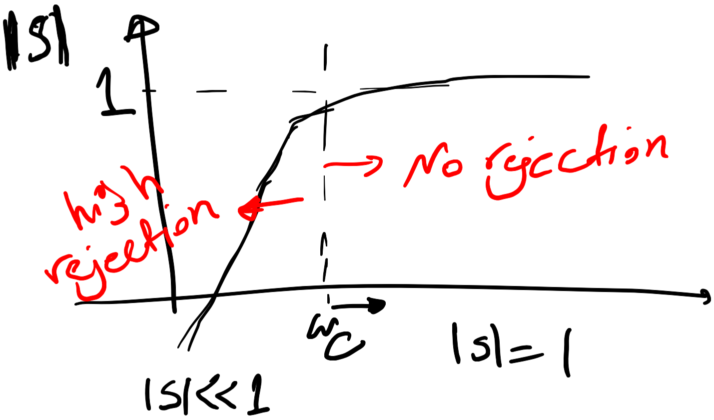
$$S(s) = \frac{V_e}{V_i} = \frac{1}{1 + L(s)} \rightarrow \text{dictates}$$

- error dynamics
- v_i disturbance rejection
- if $A(s)$ changes, how much $G(s)$ is affected

$$= \frac{dG/G}{dA/A}$$

$$T(s) = \frac{L(s)}{1 + L(s)} = \frac{A(s)f}{1 + A(s)f} \rightarrow \text{dictates}$$

- tracking
- rise_time → Bandwidth
- overshoot → Resonant Peak



$$S(s) = \frac{1}{1+L(s)} \quad , \quad T(s) = \frac{L(s)}{1+L(s)}$$

$$\begin{cases} |L| \gg 1 \\ \omega \ll \omega_c \end{cases} \Rightarrow \begin{array}{l} |S| \approx 0 \\ |T| \approx 1 \end{array}$$

$$\begin{cases} |L| \ll 1 \\ \omega \gg \omega_c \end{cases} \Rightarrow \begin{array}{l} |S| = 1 \\ |T| = |L| \\ \angle T = L \end{array}$$