5 (1. Halbtag) | Operationsverstärker

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3.1 A

The equation hold

$$\frac{1}{\nu} = \frac{1}{\nu_0} + k \qquad \nu = \frac{1}{\frac{1}{\nu_0} + k}. \tag{3.1}$$

For $k = 0.1$, $\nu_0 = 10^4$ and $\nu_0 = 10^5$

$$\nu_1 \approx 9.990 \qquad \nu_2 \approx 9.999. \tag{3.2}$$

The approximation $\nu = \frac{1}{k}$ results in

$$\nu_{\text{Näh}} = 10. \tag{3.3}$$

The deviation of ν_1 and ν_2 from $\nu_{\text{Näh}}$ lie at 0.001% and 0.0001% respectively.

3.2 B

It hold

$$\begin{aligned} U_x &= U_{\text{in}} - kU_{\text{out}} & (3.4)\\ \Leftrightarrow \quad &= U_{\text{in}} - kv_0 U_x \\ \Leftrightarrow \quad &= \frac{U_{\text{in}}}{1 + v_0 k}. & (3.5) \end{aligned}$$

For $k = 0.1$, $v_0 = 10^5$ and $U_{\text{in}} = 1\,\text{V}$

$$U_x \approx 0.0001\,\text{V}. \tag{3.6}$$

3.3 C

Let there be a common mode signal with $\Delta U_+ = \Delta U_- = +\Delta U_{\text{in}}$. then

$$\Delta U_+ = \Delta U_E + \Delta U_1 \quad \Delta U_- = \Delta U_E + \Delta U_1. \tag{3.7}$$

from this follows $\Delta U_{\text{in}} = \Delta U_E + \Delta U_1$. The output voltage is

$$\Delta U_{\text{out}} = R_C \cdot \Delta I_C. \tag{3.8}$$

At point 1,

$$I_1 = 2I_E. \tag{3.9}$$

Therefore

$$\begin{aligned} \Delta U_{\text{in}} &= R_E \cdot \Delta I_E + R_1 \cdot 2\Delta I_E \\ &= \Delta I_E \left(R_E + 2R_1\right) \approx \Delta I_E \cdot 2R_1. \end{aligned} \tag{3.10}$$

At the node U_{out} applies

$$\Delta I_E = \Delta I_C \Rightarrow \Delta U_{\text{out}} = R_C \cdot \Delta I_E. \tag{3.11}$$

The amplification results in

$$v_{CM} = \frac{\Delta U_{\text{out}}}{\Delta U_{\text{in}}} = \frac{R_C}{2R_1}. \tag{3.12}$$

The common mode suppression is

$$10 \log \left(\frac{R_E}{R_1}\right) = 10 \log \left(\frac{1\,\text{k}\Omega}{100\,\text{k}\Omega}\right) = -20\,\text{dB}. \tag{3.13}$$

3.4 D

The frequency dependence of the impedance of a capacitor is

$$Z_1 = \frac{1}{\text{i}\omega C} = \frac{1}{\text{i}2\pi f C} \tag{3.14}$$

$$|Z_1| = \left|\frac{1}{\text{i}\omega C}\right| = \frac{1}{2\pi f C}. \tag{3.15}$$

The gain as a function of frequency is

$$v\left(f\right) = 1 + \frac{Z_2}{|Z_1|} = 1 + R2\pi f C. \tag{3.16}$$

The limits are

$$\lim_{f\to 0} \left[1 + R2\pi f C\right] = 1 \quad \lim_{f\to\infty} \left[1 + R2\pi f C\right] = \infty. \tag{3.17}$$

For $|Z_1| = R$ it has to hold that

$$\frac{1}{2\pi f C} = R \Leftrightarrow f = \frac{1}{2\pi RC}. \tag{3.18}$$

With concrete values $Z_1 = R = 100\,\text{k}\Omega$ and $Z_1 = C = 100\,\text{nF}$, the frequency is

$$f = \frac{1}{2\pi RC} \approx 15.92\,\text{Hz} \Rightarrow v\left(f\right) \approx 2. \tag{3.19}$$

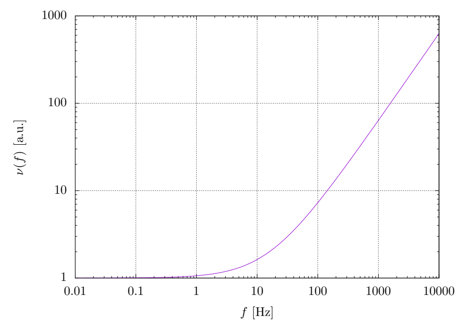

Figure 1: Time dependend amplification of a non–invertible amplifier as a BODE–plot

3.5 E

Let

$$v = \frac{U_{\text{out}}}{U_{\text{in}}} = -\frac{Z_2}{Z_1}. \tag{3.20}$$

The minus sign results from the negative feedback. Because of the golden rule $U_- = U_+ = 0\,\text{V}$, the negative feedback has a different sign compared to the input signal.

The input impedance is very high and the output impedance very low.

3.6 F

The first KIRCHHOFF's law states (EINSTEIN notation)

$$\sum_i I_i = -I_{\text{out}} \tag{3.21}$$

$$\Leftrightarrow \quad \frac{U_i}{R_i} = -\frac{U_{\text{out}}}{R_0} \tag{3.22}$$

$$\Leftrightarrow \quad -\frac{R_0}{R_i} U_i = U_{\text{out}} \tag{3.23}$$

$$\Leftrightarrow \quad c_i U_i = U_{\text{out}}. \tag{3.24}$$

3.7 G

$$U_+ = U_2 \frac{R_2}{R_1 + R_2} \qquad |\text{voltage divider} \tag{3.25}$$

$$U_- = U_+ \qquad |\text{golden rule} \tag{3.26}$$

$$I_1 = \frac{U_1 - U_-}{R_1} \qquad |\text{OHM's law} \tag{3.27}$$

$$I_2 = I_1 \qquad |\text{golden rule} \tag{3.28}$$

$$I_2 = \frac{U_- U_{\text{out}}}{R_2} \qquad |\text{OHM's law.} \tag{3.29}$$

The final result $U_{\text{out}} = \frac{R_2}{R_1} (U_2 - U_1)$ can be calculated using the above relations.

3.8 H

4 Auswertung

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