ELEC-E3120 Analysis and Design of Electronic Circuits

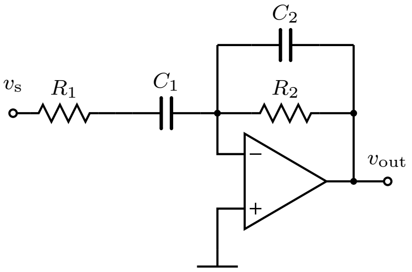
Exam 10.12.2015

This exam includes five problems. Note that the last one is at the other side of the paper. Each problem gives 10 points at maximum.

1.

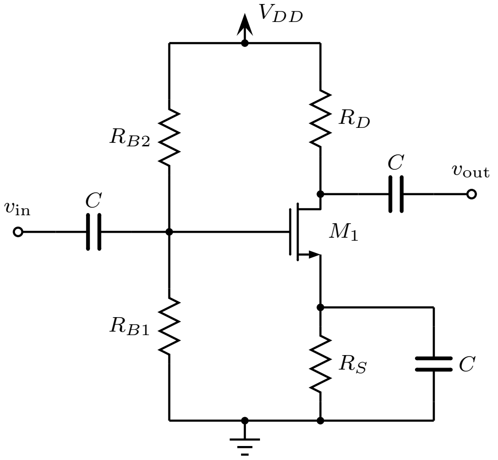
Answer shortly, with a few words, to the following questions.
a) Name the following symbols related to feedback: A_F, A, β, and $A\beta$.
b) You need to know the frequency limit of a transistor biased as an amplifier. Which transistor model do you use? Draw the model.
c) How can you recognize an active circuit from its scattering parameters?
d) When analyzing digital systems, what does multiplying by z^{-1} mean?

2.



An acoustic sensor is represented by v_s in the figure. The band-pass filter in the figure is specified to pass an input signal with its specified bandwidth. Determine the bandwidth and center frequency of the circuit when the op-amp is assumed ideal.
Hint: Determine first the transfer function $\frac{v_{out}}{v_s}$.

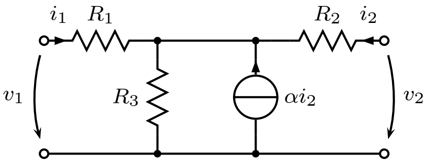
3.



The operating point of the transistor is $V_{GS} = 3\,\text{V}$, $V_{DS} = 10\,\text{V}$ and $I_D = 4\,\text{mA}$.
a) Calculate the open-circuit voltage gain for the CS-amplifier.
b) Calculate the input impedance and the output impedance of the CS-amplifier.
You can neglect the channel-length modulation in this exercise. Capacitances C are large at the frequency of the input signal.
Hint: Start by drawing the small signal model.

$$R_{B1} = 10\,\text{k}\Omega \quad R_{B2} = 30\,\text{k}\Omega \quad R_D = 2\,\text{k}\Omega$$
$$R_S = 500\ \Omega \quad V_{DD} = 20\,\text{V} \quad k_n' \tfrac{W}{L} = 2\,\text{mA/V}^2$$
$$V_t = 1\,\text{V}.$$

4.



An electronic amplifier has the circuit shown in the figure. Determine the impedance parameters for the circuit.

$$z_{11} = \left.\frac{v_1}{i_1}\right|_{i_2=0} \qquad z_{12} = \left.\frac{v_1}{i_2}\right|_{i_1=0}$$

$$z_{21} = \left.\frac{v_2}{i_1}\right|_{i_2=0} \qquad z_{22} = \left.\frac{v_2}{i_2}\right|_{i_1=0}$$

5.

Answer this question by writing and drawing on this paper and returning it.

a) Name the type of filter for each of the figures.

b) Mark f_0, f_L and f_H on the figure(s) (where applicable!).

c) What are the locations of poles and zeros in each case?

Note: all filters are of the second-order!

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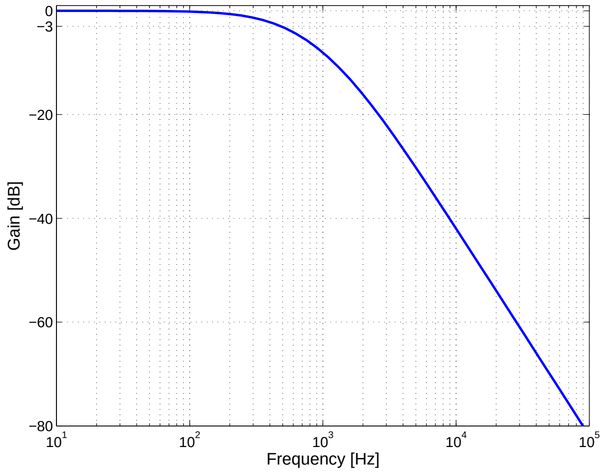

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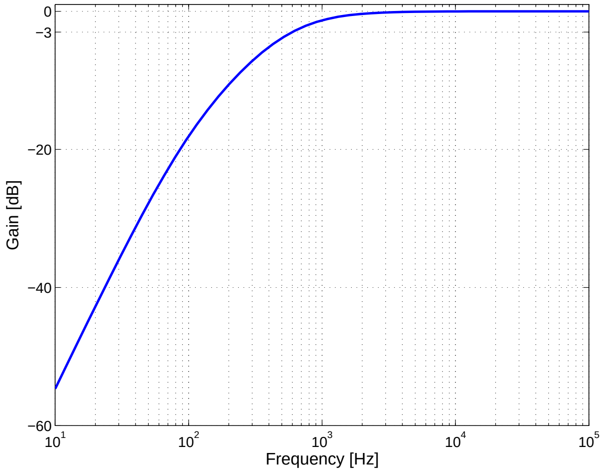

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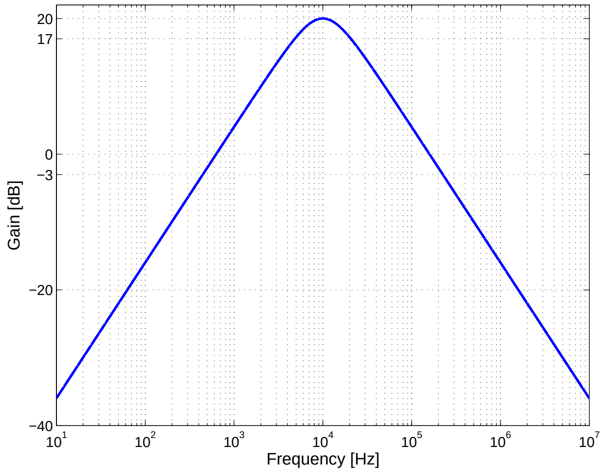

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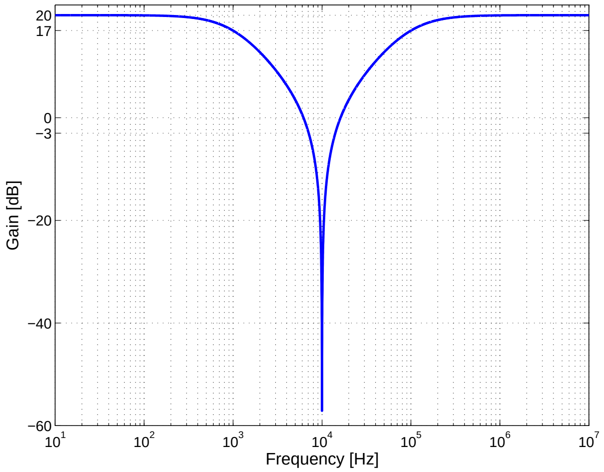

Name: ______________________________ Student number: __________________

0.1

Answer shortly, with a few words, to the following questions.
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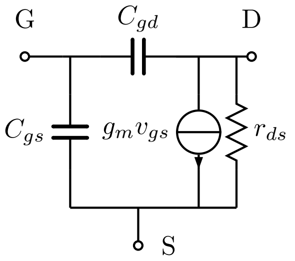
a)

- A_F: $A_F = \frac{A}{1+A\beta}$, closed loop gain
- A: Open loop gain
- β: Feedback
- $A\beta$: Loop Gain

b)



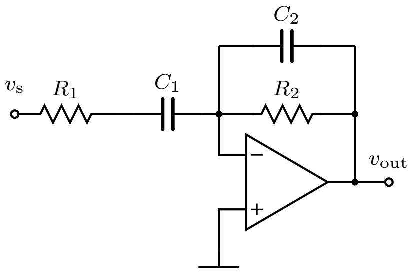
$$\begin{aligned} g_m &= \sqrt{2 I_D k_n' \frac{W}{L}} \\ &= k_n' \frac{W}{L}(V_{GS} - V_{tn}) \\ r_{ds} &\approx \frac{1}{\lambda I_D} \end{aligned}$$

c) If the magnitude of any S parameter is larger than 1 or

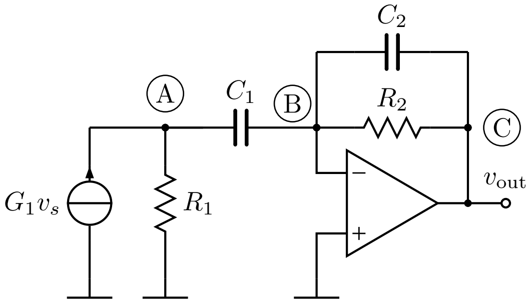
$$|S_{11}|^2 + |S_{21}|^2 > 1$$

d) Multiplying by z^{-1} models a delay of one time pediod of sampling frequency.

0.2



An acoustic sensor is represented by v_s in the figure. The band-pass filter in the figure is specified to pass an input signal with its specified bandwidth. Determine the bandwidth and center frequency of the circuit when the op-amp is assumed ideal.
Hint: Determine first the transfer function $\frac{v_{\text{out}}}{v_s}$.



$$\begin{bmatrix} G_1+sC_1 & -sC_1 & 0 \\ -sC_1 & G_2+sC_1+sC_2 & -G_2-sC_2 \\ 0 & -G_2-sC_2 & G_2+sC_2 \end{bmatrix} \begin{bmatrix} U_{\text{A}} \\ U_{\text{B}} \\ U_{\text{C}} \end{bmatrix} = \begin{bmatrix} G_1 v_s \\ 0 \\ I_{\text{out}} \end{bmatrix}$$

Same voltage in input nodes of opamp. Node B is at the ground potential and the corresponding column can be removed.

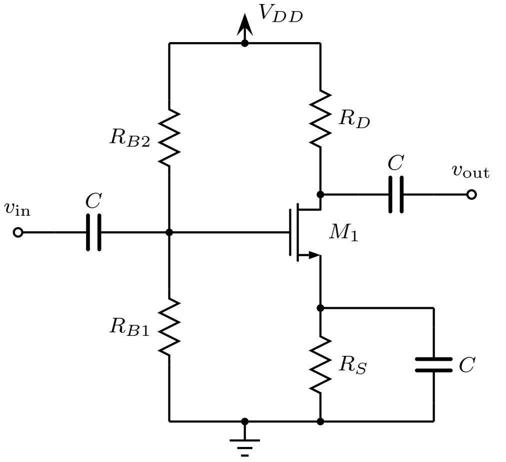
$$\begin{bmatrix} G_1+sC_1 & 0 \\ -sC_1 & -G_2-sC_2 \end{bmatrix} \begin{bmatrix} U_{\text{A}} \\ U_{\text{C}} \end{bmatrix} = \begin{bmatrix} G_1 v_s \\ 0 \end{bmatrix}$$

$$H(s) = \frac{v_{\text{out}}}{v_s} = -\frac{-sC_1G_1}{(G_1+sC_1)(G_2+sC_2)} = \frac{sC_1G_1}{s^2C_1C_2+s(C_1G_2+C_2G_1)+G_1G_2} = \frac{h(s)}{s^2+s\frac{\omega_0}{Q}+\omega_0^2}$$

$$\omega_0 = \sqrt{\frac{G_1G_2}{C_1C_2}}$$

$$\Delta\omega = \frac{\omega_0}{Q} = \frac{C_1G_2+C_2G_1}{C_1C_2}$$

0.3



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$R_S = 500\ \Omega \quad V_{DD} = 20\,\text{V} \quad k'_n \frac{W}{L} = 2\,\text{mA/V}^2$
$V_t = 1\,\text{V}$.

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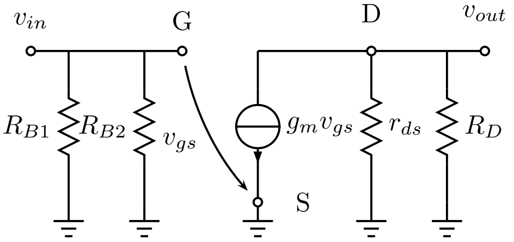
a) Small signal:



Now we can calculate the parameters with the DC-operation point values:

$$g_m = \sqrt{2 I_D k'_n \frac{W}{L}} = k'_n \frac{W}{L}(V_{GS} - V_{tn}) = 4\text{mS}$$
$$r_{ds} \approx \frac{1}{\lambda I_D} \approx \infty,$$

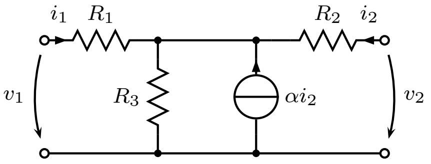
because we were told to ignore the channel length modulation, so that means there is no resistor r_{ds} in our circuit.
Next, we will calculate the open circuit voltage (as we have no load, the output of the open circuit will just be the same as v_{out} in our figure):

$$v_{out} = -g_m R_D v_{gs} = -g_m R_D (v_g - v_s) = -g_m R_D (v_{in} - 0) = -g_m R_D v_{in} \tag{1}$$
$$A_{vo} = \frac{v_{out,open}}{v_{in}} = -g_m R_D = -8 \tag{2}$$

b) Using the figure from a-part, we get

$$R_{in} = R_{B1} || R_{B2} = 7.5\text{k}\Omega \tag{3}$$
$$R_{out} = R_D = 5\text{k}\Omega \tag{4}$$

0.4



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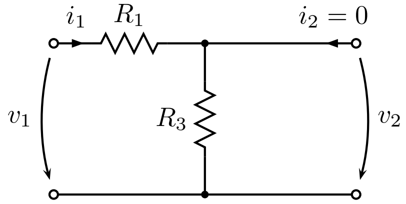
$$z_{21} = \left.\frac{v_2}{i_1}\right|_{i_2=0} \qquad z_{22} = \left.\frac{v_2}{i_2}\right|_{i_1=0}$$

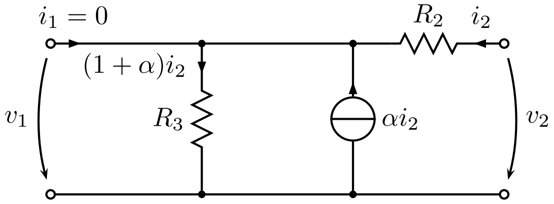
Assume first, $i_2 = 0$:



$$z_{11} = \left.\frac{v_1}{i_1}\right|_{i_2=0} = R_1 + R_3$$

$$z_{21} = \left.\frac{v_2}{i_1}\right|_{i_2=0} = R_3$$

Assume next, $i_1 = 0$:



Applying the Kirchhoff's current law, the current through the resistor R_3 is $(1+\alpha)i_2$.

$$z_{12} = \left.\frac{v_1}{i_2}\right|_{i_1=0} = (1+\alpha)R_3$$

$$z_{22} = \left.\frac{v_2}{i_2}\right|_{i_1=0} = R_2 + (1+\alpha)R_3$$

0.5

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b) Mark f_0, f_L and f_H on the figure(s) (where applicable!).

c) What are the locations of poles and zeros in each case?

Note: all filters are of the second-order!

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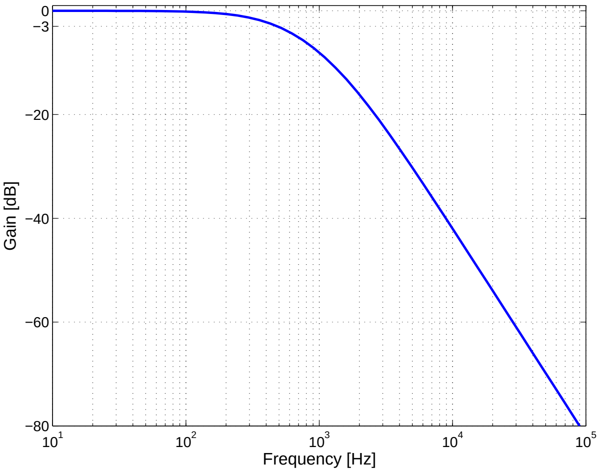

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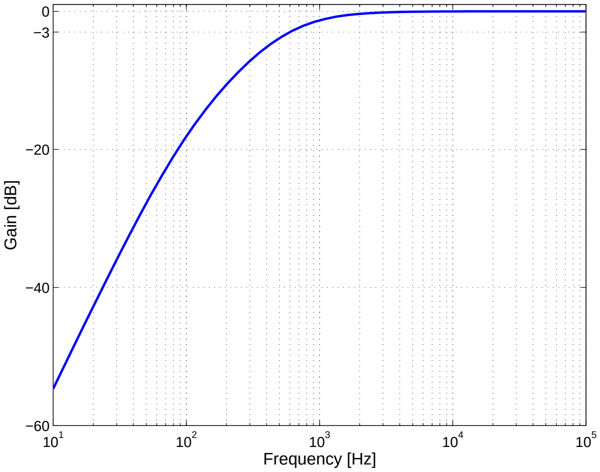

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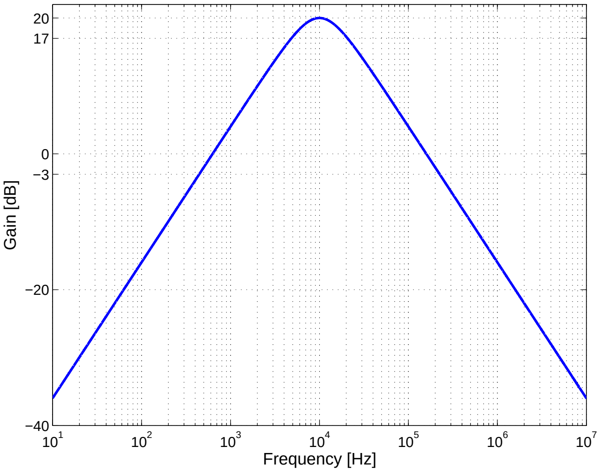

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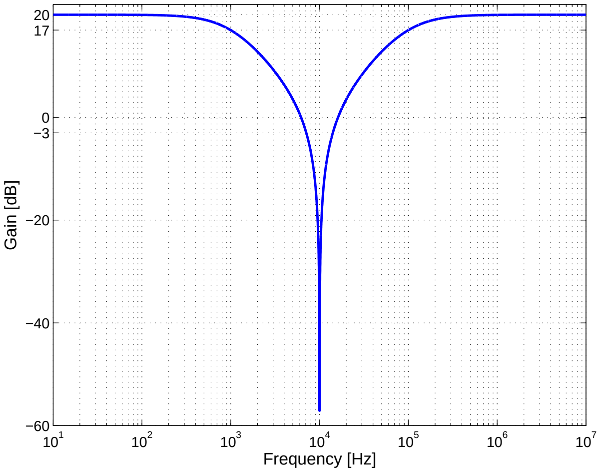

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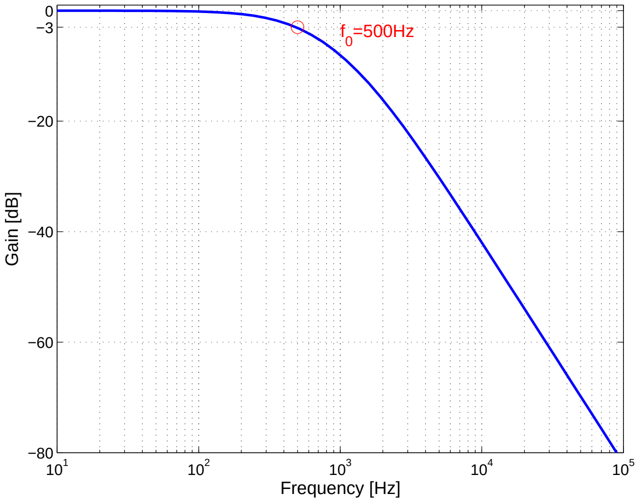
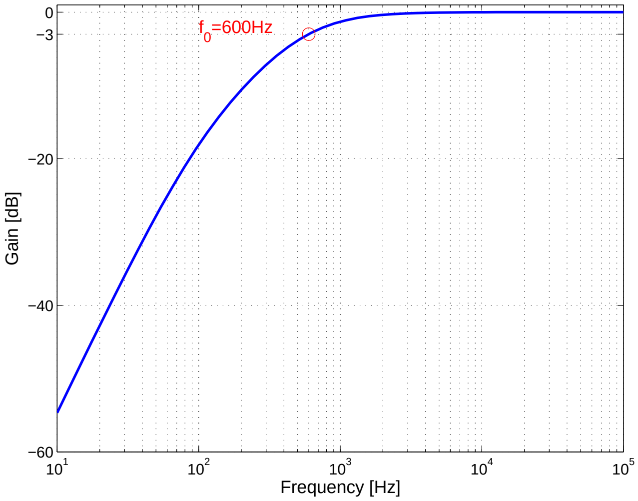
a) Low-pass filter.

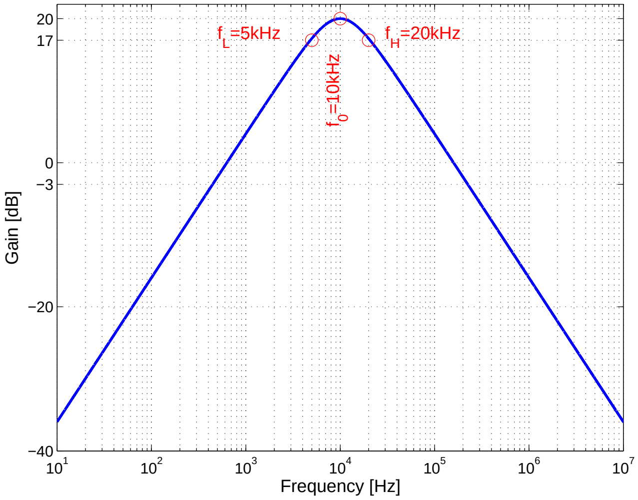
Two poles at $f_0 = 500\text{Hz}$ (two zeroes at ∞).



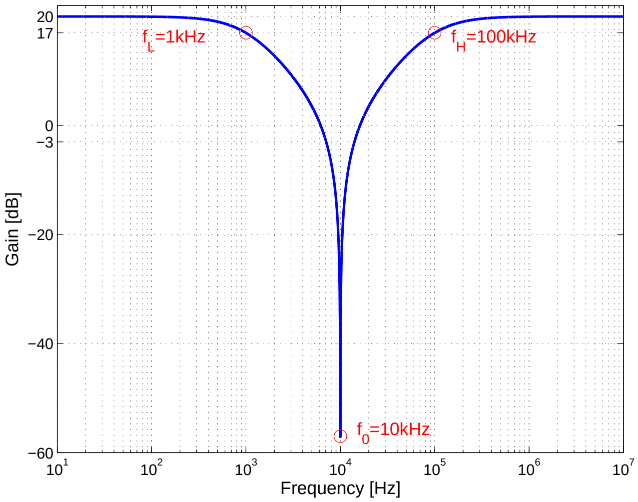
b) High-pass filter.
Two zeroes at 0 and two poles at $f_0 = 600\text{Hz}$.



c) Band-pass filter.
One zero at 0, two poles at $f_0 = 10\text{kHz}$ (one zero at ∞).



d) Band-stop filter.
One pole at $f_L = 1\text{kHz}$, two zeroes at $f_0 = 10\text{kHz}$ and one pole at $f_H = 100\text{kHz}$.



20
17
0
−3
−20
−40
−60
Gain [dB]
10^1
10^2
10^3
10^4
10^5
10^6
10^7
Frequency [Hz]
f_L=1kHz
f_H=100kHz
f_0=10kHz