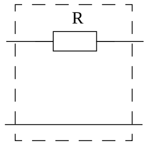
Exercises

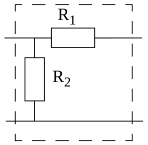
• Active Components

Exercise K1

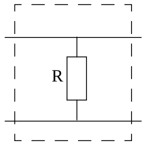
Determine the two-port parameters for the circuits below.



a) y-parameters



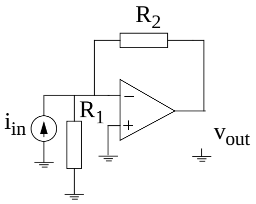
b) h-parameters



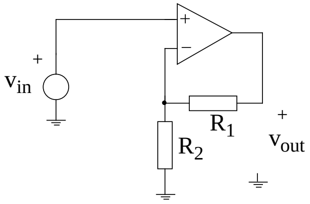
c) z-parameters

Exercise K2

Which type of feedback is used for the circuits below? Calculate the loop gain, input/output impedance and the transfer function for the circuits. The voltage gain of the op-amp is a and the output impedance is z_o.



a)



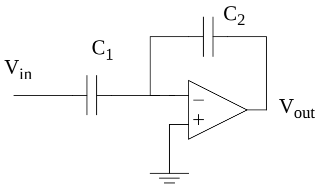
b)

Exercise K3

Determine an expression for the low frequency input impedance of the CG-amplifier. Assume that the load impedance at the output is R_{out}.

Exercise K4

Determine the loop-gain, feedback factor β and total transfer function for the circuit below.



Exercise K5

Determine the low frequency gain of the cascode amplifier.

Exercise K6

Calculate the equivalent input noise of the two-stage opamp.

Exercise K7

Consider the transistor as a two-port. Derive the two-port parameters. Choose proper parameters. How do these correspond to the equivalent small signal schematics?

Exercise K8

Show how a transistor can be used as a resistor. In what region should the transistor operate? Explain how this resistance depends on the drain, gate, source and bulk voltage.

Exercise K9

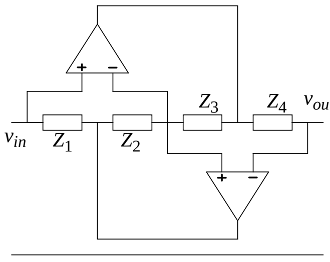
Suppose the circuit to the right has ideal operational amplifiers.

Derive the input impedance and the K-matrix for the circuit.

What is the advantage with a circuit like this?

How should the components (impedances) be chosen to let the circuit simulate an inductance?

Discuss what will happen if the operational amplifiers are non-ideal. How will the input impedance change, etc.?

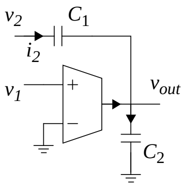


Exercise K10

Derive the transfer function of the G_m-C circuit.

Also derive the transfer function when assuming that the transconductor has a finite output resistance, R_{out}.

What is the disadvantage with this circuit?



• Active Filters

Exercise K11

Realize the filter having the transfer function

$$H(s) = \frac{1\times10^6}{s^2 + 3\times10^5 \cdot s + 6\times10^{10}}$$

Use

a) Use Operational amplifiers
b) Use G_m-C elements.

Exercise K12

Realize the filter having the transfer function

$$H(s) = \frac{-1\times10^6 \cdot (s-10^4)}{s^2 + 3\times10^5 \cdot s + 6\times10^{10}}$$

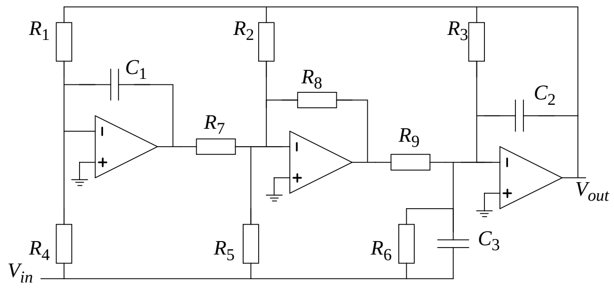
Use

a) Use Operational amplifiers
b) Use Gm-C elements.

Exercise K13

Derive the transfer function for the circuit.

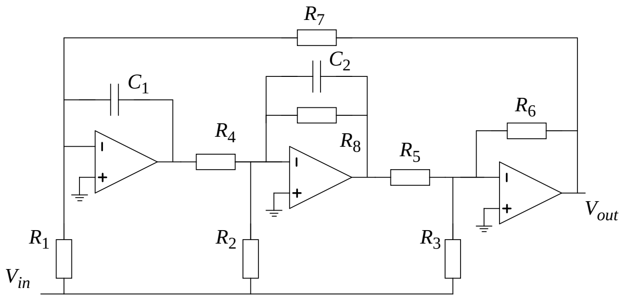
Sketch the signal flow chart using amplifiers, summations and integrators. Also sketch the magnitude response.



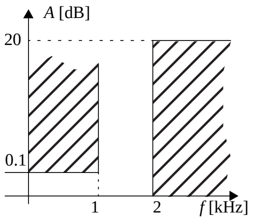
Exercise K14

Derive the transfer function for the circuit.

Sketch the signal flow chart using amplifiers, summations and integrators. Also sketch the magnitude response.



Exercise K15



Design a continous-time Butterworth filter that meets the following specification

Pass band: $0 \le f \le 3.5\,\text{kHz}$, $A_{max} = 1\,\text{dB}$

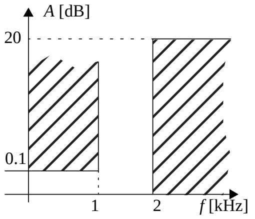
Cut-off band: $f \ge 10\,\text{kHz}$, $A_{min} = 20\,\text{dB}$

Use

a) RLC components
b) Active RC
c) MOSFET-C
d) G_m-C

Derive the values of all components and show the flow graphs you are using in each step. Termination resistances in corresponding passive RLC filter are supposed to be 1kΩ. The order is found to be $N = 3$ and the normalized filter values are: $C_{3n} = 1$, $L_{2n} = 2$ and $C_{1n} = 1$.

Exercise K16



Design an active continous-time elliptic leapfrogfilter with following specification:

Pass band: $0 \le f \le 1\,\text{kHz}$, $A_{max} = 0.1\,\text{dB}$

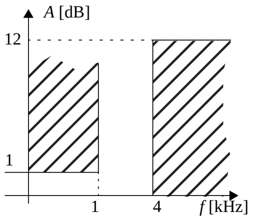
Cut-off band: $f \ge 2\,\text{kHz}$, $A_{min} = 20\,\text{dB}$

Use

a) RLC components
b) Active RC
c) MOSFET-C
d) G_m-C

Derive the values of all components and show the flow graphs you are using in each step. Termination resistances in corresponding passive RLC filter are supposed to be 1kΩ. The order is found to be $N = 3$ and the normalized filter values are: $C_1' = C_3' = 0.8740$, $C_2' = 0.2411$ and $L_2' = 0.9083$,

Exercise K17



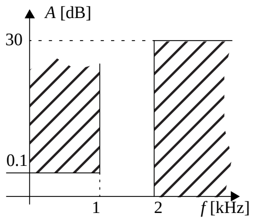
Synthesize a continous-time low-pass butterworth filter of order $N = 2$ according to the specification.

Use

a) RLC components
b) Active RC
c) MOSFET-C
d) G_m-C

Derive the values of all components and show the flow graphs you are using in each step. Termination resistances in corresponding passive RLC filter are supposed to be 1kΩ. The normalized filter values are $C_1 = 1.4142$ and $L_2 = 1.4142$.

Exercise K18



Synthesize a continous-time low-pass elliptic filter of according to the specification.

Use

- a) RLC components
- b) Active RC
- c) MOSFET-C
- d) G_m-C

Derive the values of all components and show the flow graphs you are using in each step. Termination resistances in corresponding passive RLC filter are supposed to be 1kΩ. The filter order is found to be $N = 5$ and the normalized filter values are $C_{1,n} = 1.05745$, $C_{2,n} = 0.10836$, $L_{2,n} = 1.25765$, $C_{3,n} = 1.71457$, $C_{4,n} = 0.30465$, $L_{4,n} = 1.04518$, $C_{5,n} = 0.89926$.

Exercise K19

Discuss the concept of gyrators. Show some different ways to implement an inductor.

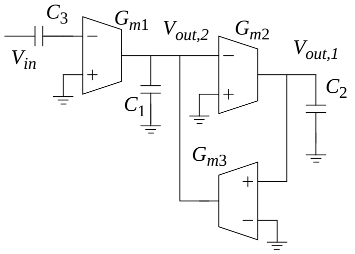
Exercise K20

Discuss why floating resistors or capacitances should not be used in a G_m-C filter.

Exercise K21

How could the influence of parasitic capacitances in a G_m-C filter be reduced?

Exercise K22



Determine the transfer function of the G_m-C circuit.

What is the cut-off frequency?

What is the Q factor of the circuit?

What are the disadvantages using this structure?

Exercise K23

Scale the filter so that $|X_i/E|_{max} = 1$ for each node X_i. Find the scaling parameters. The measured maximum values are:

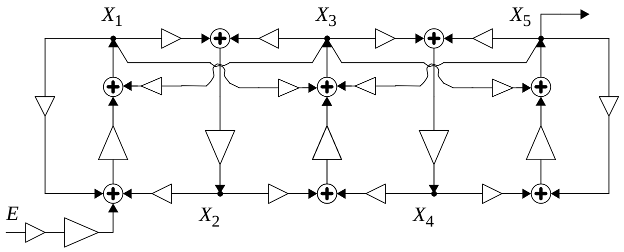
$|X_1/E|_{max} = 0.92$ för $\omega T = 41°$

$|X_2/E|_{max} = 1.33$ för $\omega T = 39°$

$|X_3/E|_{max} = 0.86$ för $\omega T = 37°$

$|X_4/E|_{max} = 1.25$ för $\omega T = 37°$

$|X_5/E|_{max} = 0.5$ för $\omega T = 0°$

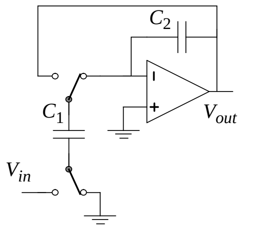


• SC Circuits

Exercise K24

Discuss how sampled noise can be modelled. What specific phenomenon occur when considering the $1/f$-noise?

Exercise K25



Derive the transfer function for the SC circuit to the right, when

a) $C_1 = C_2$

b) $C_1 = 1.12 \cdot C_2$. (Why $C_1 = 1.12 \cdot C_2$?)

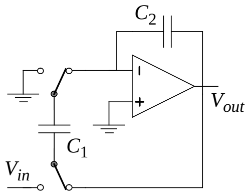
Sketch the pole/zero placement and the amplitude characteristics. What kind of a circuit is this?

Is the circuit sensitive to parasitics?

What will happen if the operational amplifier is non-ideal?

Derive the feedback factor of both phases.

Exercise K26



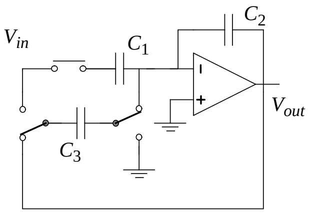
Derive the transfer function for the SC circuit to the right, How should the capacitances be chosen if the circuit is to be used as a sample-and-hold circuit?

Is the circuit sensitive to parasitics?

What will happen if the operational amplifier is non-ideal?

Derive the feedback factor of both phases.

Exercise K27



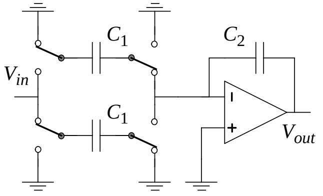
Derive the transfer function for the SC circuit to the right, How should the capacitances and the input voltage v_1 be chosen if the circuit is to be used as an all-pass filter?

Is the circuit sensitive to parasitics?

What will happen if the operational amplifier is non-ideal?

Derive the feedback factor of both phases.

Exercise K28



Derive the transfer function for the circuit.

Which operation does the circuit perform?

Why is the value sampled over two “equal” capacitances?

Exercise K29

Discuss what techniques to use to minimize the influence of CFT, clock feedthrough. What advantages and disadvantages can be found with these techniques? Also explain how different clock phases should be chosen in a SC circuit. Why do they have to be non-overlapping.

Exercise K30

Discuss the concept of switch sharing in SC circuits.

Exercise K31

Suppose that for the LDI transformation the following expression is used

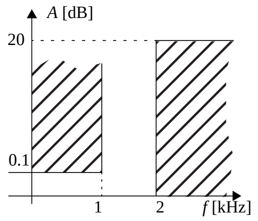
$$s = z^{1/2} - z^{-1/2} = \frac{1 - z^{-1}}{z^{-1/2}}$$

There is no constant s_0. How should a reference filter in this case be (frequency) scaled to get the wanted mapping from the s-plane to the z-plane.

Exercise K32

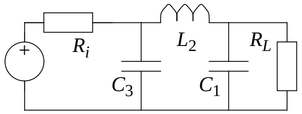
What properties must a filter have if the LDI transform shall be used.

Exercise K33



Design an LDI filter that fulfills the attenuation specification according to the figure to the right. Choose a buitterworth reference filter. Compensate the filter so that errors due to transformation approximations are minimized.

Scale the internal nodes of the filter.



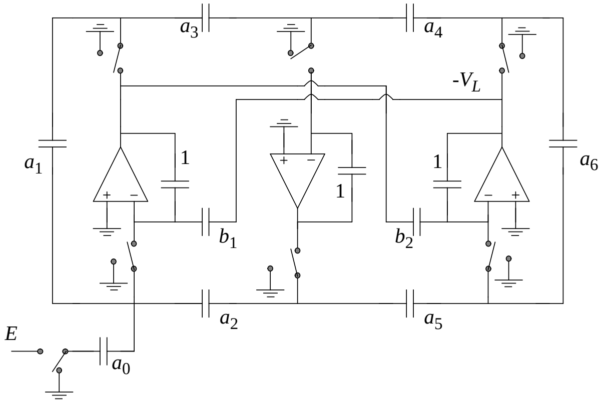
The order is found to be $N = 3$. The normalized values found from table are

$C_{3n} = 1$, $L_{2n} = 2$, $C_{1n} = 1$ and

$R_i = R_L = 1k\Omega$

Exercise K34

The SC-filter below simulates an elliptic reference filter. The filter is not scaled and the gain is not at its maximum of 0dB. How large is the gain? What components in the circuit should be changed (and how much) to achieve a maximum gain?



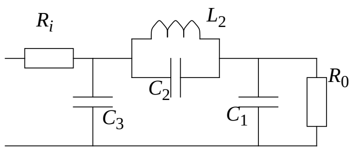
The values are given by

$$\alpha_1 = C_1 + C_2 - \frac{1}{2s_0R_i}, \ \alpha_2 = C_2 + C_3 - \frac{1}{2s_0R_L}$$

$$a_0 = a_1 = a_2 = \frac{1}{s_0R\alpha_1}, \ a_5 = a_6 = \frac{1}{s_0R\alpha_2}, \ a_3 = a_4 = \frac{R}{s_0L_2},$$

$$b_1 = \frac{C_2}{\alpha_1}, \ b_2 = \frac{C_2}{\alpha_2}, \ R = R_i = R_L$$

Exercise K35



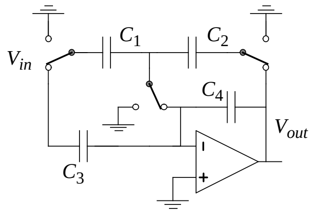
Design a third order SC low pass filter with cut-off frequency $f_c = 3.4\,\text{kHz}$ and sampling frequency $f_s = 128\,\text{kHz}$. The ripple in the pass band is less than 0.02dB.

Choose an elliptic reference filter with modular angle $20°$. Design a leapfrog scheme that is mapped to the discrete-time domain using the LDI transformation. Compensate the filter so that errors due to transformation approximations are minimized.

Normalized values from table are:

$$R_i = R_0 = 1k\Omega,\ C_{1,n} = C_{3,n} = 0.5275,\ C_{2,n} = 0.1921,\ L_{2,n} = 0.7700$$

Exercise K36



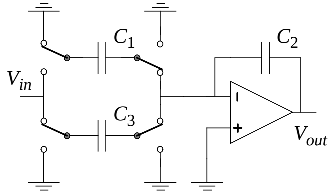
Derive the transfer function

$$H(z) = \frac{V_2(z)}{V_1(z)}$$

for the circuit and find poles and zeros. Sketch the amplitude characteristics.

What operation does the circuit perform?

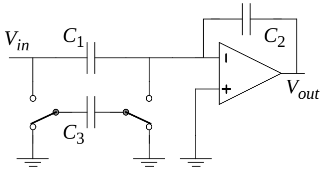
Exercise K37



Discuss the circuit to the right. What dependence is there between the input and output signal?

How is the transfer function depending on the input signal?

Exercise K38



What conditions must be fulfilled when the circuit can be used as a bilinear integrator.

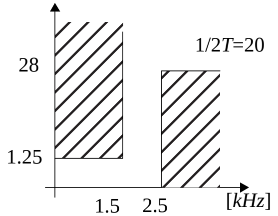
A bilinear relation is given by

$$s = \gamma \cdot \frac{z-1}{z+1}$$

Exercise K39

Concludingly, how should the signals be switched to minimize the influence of parasitic capacitances (in the switches) for an SC circuit?

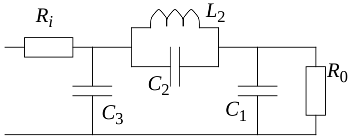
Exercise K40



Synthesize an LDI filter that fulfils the specification. Choose an elliptic reference filter.

Compensate the filter so that errors due to transformation approximations are minimized.

Describe how the filter can be scaled, and why.



Values found from table are:

Order $N = 3$

$\kappa^2 = 1$, hence $R_i = R_0 = 1k\Omega$

Normalized component values are

$C_{1n} = C_{3n} = 1.9314$, $C_{2n} = 0.3781$

and $L_{2n} = 0.7571$