TFE4186 Analog CMOS 1
Problem set 5
3. order Tsjebysjev switch-cap filter

Overview:

In this exercise we will design a switched capacitor (SC) 20KHz low-pass Tsjebysjev filter.

A Tsjebysjev filter has a very steep transition from pass-band to stop-band. To achieve this, some ripple is allowed in the passband. The amplitude response of an *n*-th order normalized Tsjebysjev filter is given by (1).

$$|H(j\omega)|^2 = \frac{1}{1+\varepsilon^2 T_n^2(\omega)} \tag{1}$$

Here ε is a constant which control the ripple response, and $T_n(\omega)$ is the Tsjebysjev-polynom of *n*-th degree. For $n = 3$, $T_n(\omega)$ equals $4\omega^3 - 3\omega$. The corner frequency is given by $\omega = 1$.

From this we can hand-calculate the desired transfer function, but we can also find it from a filter table. For a 3.order filter with 2dB ripple we get the function given by (2):

$$H(s) = \frac{\omega_1}{s+\omega_1} \cdot \frac{\omega_2^2}{s^2 + a\omega_2 s + \omega_2^2} \tag{2}$$

Where:
ω_1 = 0.362
ω_2 = 0.941
a = 0.391

In this exercise we will realize the third-order Tsjebysjev filter as a first order sc-filter cascaded by a biquad sc-filter.

Specification:

DC-gain ≈ 1
Corner frequency: 20kHz
Clock frequency: 100kHz
Max allowed ripple: 2dB
Filter type: 3. degree Tsjebysjev filter

Problem 1:

Use Matlab and plot the amplitude response for the first order-, biquad- and the total 3. order Tsjebysjev filter.

Problem 2:

Show that the switched capacitor in fig. 1 is equivalent to a resistor with a resistance of R = T/C, when the sampling time period equals T.

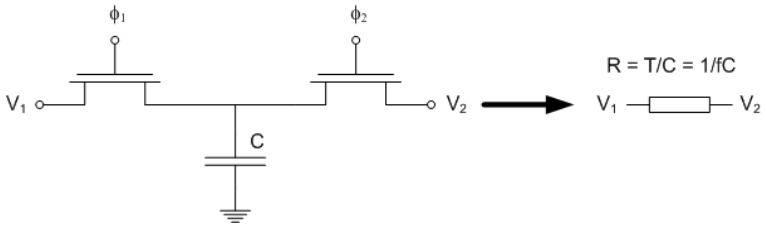

Fig. 1

Problem 3:

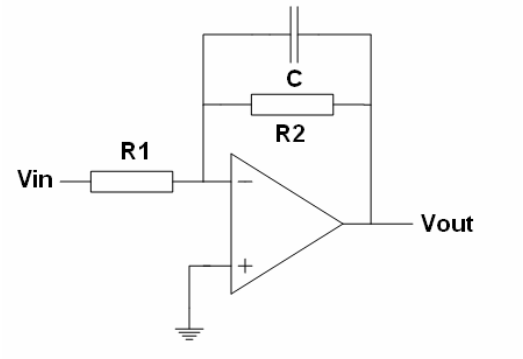

Fig 2: First order active filter

Show that:

$$H(s) = \frac{V_{out}(s)}{V_{in}(s)} = -\frac{1/RC}{s + 1/RC} = \frac{\omega_1}{s + \omega_1}$$

When $R = R_1 = R_2$ and $\omega_1 = 1/RC$

Find a switch-cap equivalent to fig. 2 with a sampling freq at 100kHz.

Perform a top level simulation in Aim-Spice of the switch-cap equivalent of fig 1, when ω_1 = 0.362 @ normalized corner frequency and f_{corner} = 20kHz. (Hint: A voltage controlled voltage source EXX can be used to simulate an ideal op-amp. Aim-spice has SXX as a macro-model for an ideal switch). A free student version of Aim-Spice can be downloaded from http://www.aimspice.com/

Problem 4:

Use eq. (2) and the given parameters for damping factor and resonant frequency, and design a second order biquad SC filter to realize the second stage of the total Tsjebysjev filter.
The student version of Aim-Spice only supports 20 transistors. Therefore you will probably not be able to simulate this second stage, but you can find component-values suitable for integration using hand-calculations. What is the capacitance spread?