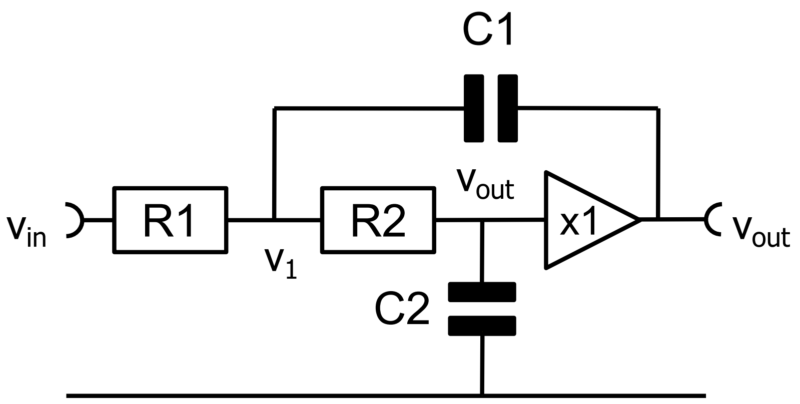
Exercise: Making a Steep Filter

Prof. Dr. P. Fischer

Lehrstuhl für Schaltungstechnik und Simulation
Uni Heidelberg

Exercise

- Just for fun, we want to design a steep Butterworth Low Pass filter
  - Let the corner frequency be 1 MHz
  - Let's chose order N=6
  - Implement it using 'Sallen and Key' stages with k=1



- After you have derived component parameters for the 3 filter stages, simulate the result.

Hints

- The poles of a Butterworth filter are placed on the left half circle with equal angles (see slide 'choosing the poles' in the lecture), i.e. with $d\phi = \pi/N$ and $r = \omega$.
- Each complex-conjugate pair of poles is handled by one 2nd order 'Sallen and Key' filter. So we need N/2 stages.
- Each filter (with dc gain 1) has a general transfer function of $1/(1+s/p_a)(1+s/p_b) = 1/(1+as+bs^2)$ where p_a and p_b are the two complex conjugate poles.

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Steps

- Step1:
  - Given a pole pair, we want to know the transfer function
  - Write $p_a = r\ (\ Sin(\phi)+i\ Cos(\phi)\ ),\ p_b = \ldots$
  - From p_a and p_b, calculate a, b
- Step2:
  - Our filter has 4 parameters (R1,R2,C1,C2), but its behaviour is described by 2 (e.g. corner, peaking), there are several ways to implement it. For example:
  - Set R1=R2=R and C2 = 1nF. This leaves us with 2 parameters
  - Derive the transfer function of a filter stage
- Step3:
  - For a given (r, ϕ) and thus (a,b), derive R and C1 by equating the coefficients of s and s^2.
- Step 4:
  - Derive (r, ϕ) for each pole-pair of the Butterworth and get R and C1 for that filter stage.