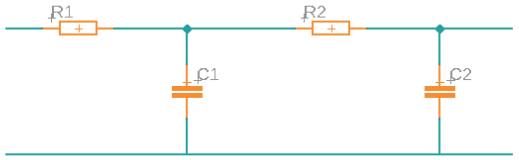
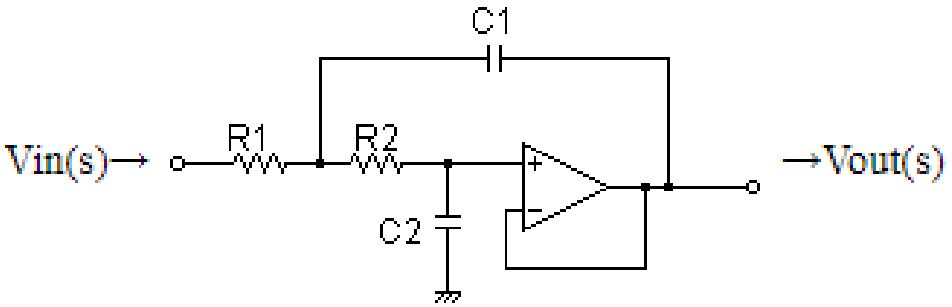
Introduction to Active Filters

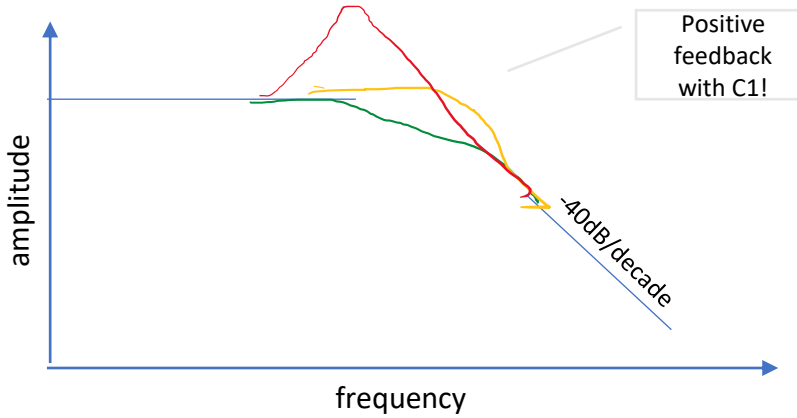


Too much attenuation at the cut-off frequency!

Much better approach is the use of active filters in e.g. sallen key topology:



Low frequencies: C1 and C2 open: → buffer amp
High frequencies: C1 and C2 short: → R1C1 and R2C2 in series



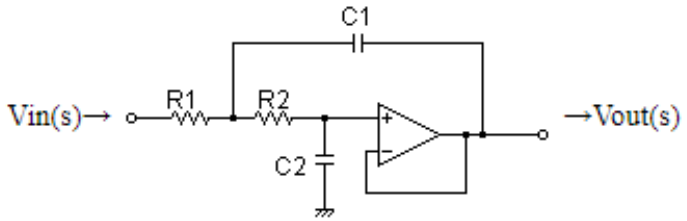
green: C1 = C2
yellow: C1 > C2
red: C1 >> C2
(different Qs)

$$Q = \frac{\sqrt{R_1 R_2 C_1 C_2}}{(R_1 + R_2)C_2}$$

Adding different stages with different Qs together allows to design Butterworth, Bessel or Chebyshev filters.

Most common topologies (lowpass):

Sallen Key

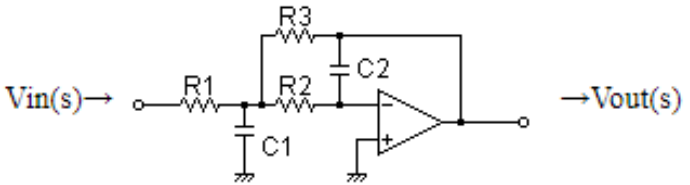


Transfer function:

$$\frac{Vout(s)}{Vin(s)} = \frac{\frac{1}{R1C1R2C2}}{s^2 + s\left(\frac{1}{R2C1} + \frac{1}{R1C1}\right) + \frac{1}{R1C1R2C2}}$$

less components
non-inverting
noise gain = 1 @stage gain 1
magnitude increase at higher frequencies
better for low-/highpass -filter

Multiple Feedback



Transfer function:

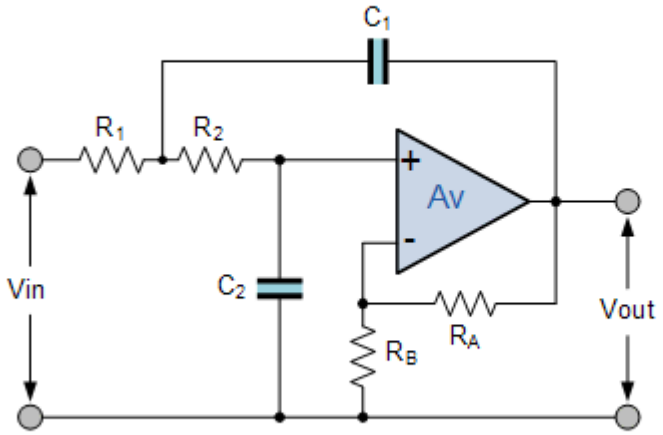
$$\frac{vo}{vi} = \frac{-\frac{1}{C1C2R1R2}}{s^2 + s\frac{1}{C1}\left(\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}\right) + \frac{1}{C1C2R2R3}}$$

more components
inverting
noise gain 1+1 = 2
better for high Q, high gain -> lower magnitude envelope increase
better for bandpass filters (high Q needed)

more by Matt Duff: https://www.youtube.com/watch?v=DUC389esZdM
http://sim.okawa-denshi.jp/en/OPseikiLowkeisan.htm

Active Filters (Sallen Key)

Second Order Low Pass Filter



Gain (Av) = $1 + \frac{R_A}{R_B}$

If Resistor and Capacitor values are different:

$$f_C = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}$$

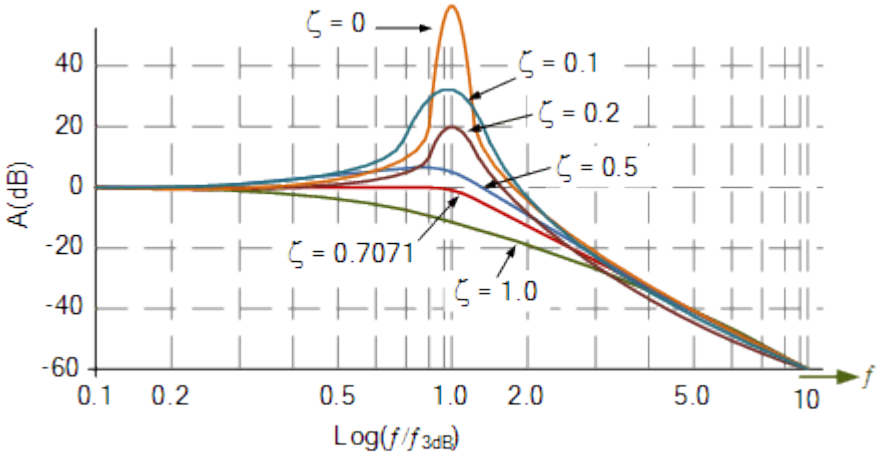
If Resistor and Capacitor values are the same:

$$f_C = \frac{1}{2\pi RC}$$

$$Q = \frac{\sqrt{R_1R_2C_1C_2}}{(R_1 + R_2)C_2}$$

Q is a measure of the peaking of a filter

Damping factor (zeta) = $\zeta = \frac{1}{2Q}$



undamped ($\zeta = 0$)
underdamped ($\zeta < 1$)
critically damped ($\zeta = 1$)
overdamped ($\zeta > 1$).

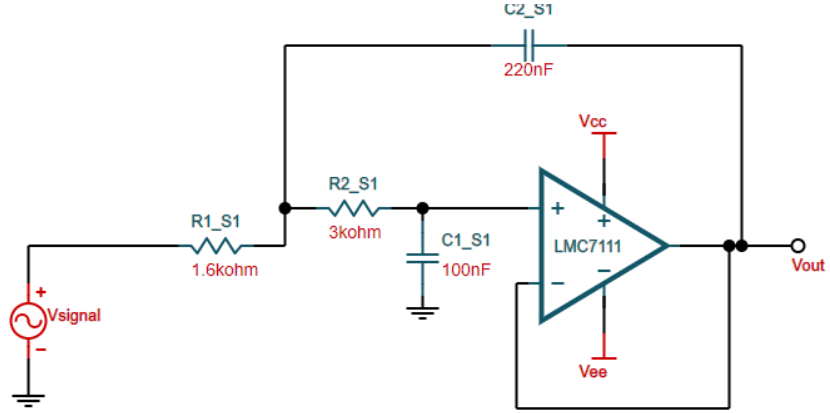
Q of 2 means, peak is aprox.
2x amplitude at fc

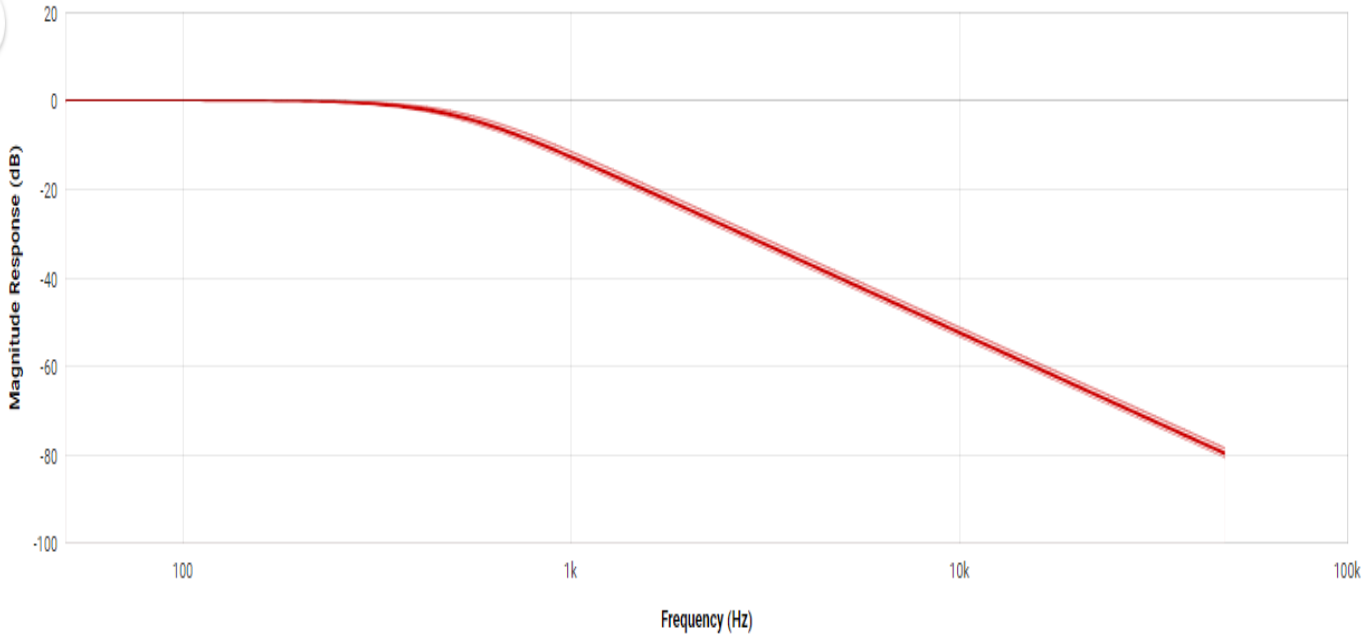
Active Filters

TEXAS INSTRUMENTS **Filter Design Tool**

Lowpass Filter-2nd order Butterworth

Passband: Ao: 1.000 V/V, Fp: 500 Hz, Rp: 1.000 dB Stopband: Fs: 5 kHz, Asb: -40.00 dB





https://www.youtube.com/watch?v=IIilxWXCj1g

Active Filters

Bench tests

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Active Filters