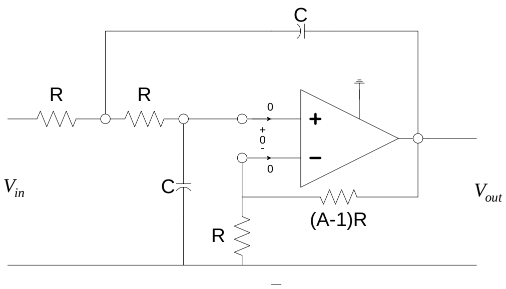
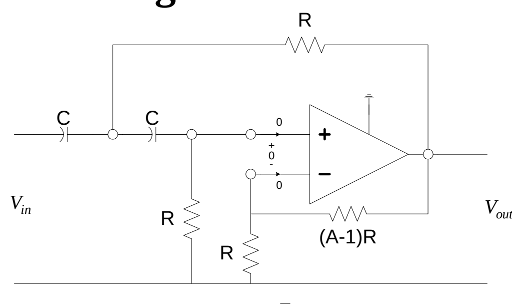
Second-Order Sallen-Key Filters

S.K. Low-Pass Filter



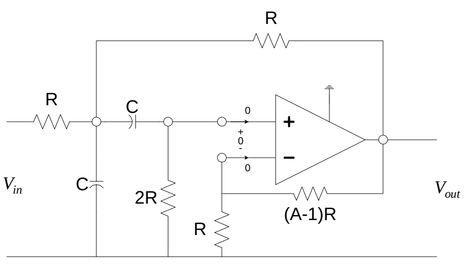
$$\omega_c = \frac{1}{RC},$$
$$A_v = A,$$
$$Q = \frac{1}{3-A}$$

S.K. High-Pass Filter



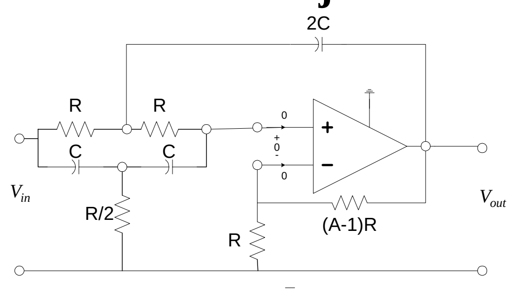
$$\omega_c = \frac{1}{RC},$$
$$A_v = A,$$
$$Q = \frac{1}{3-A}$$

S.K. Band-Pass Filter



$$\omega_o = \frac{1}{RC}$$
$$Q = \frac{1}{3-A}$$
$$A_v = AQ$$

S.K. Band-Reject Filter



$$\omega_o = \frac{1}{RC}$$
$$Q = \frac{1}{4-2A}$$
$$A_v = A$$

Properties of Sallen-Key Filters:

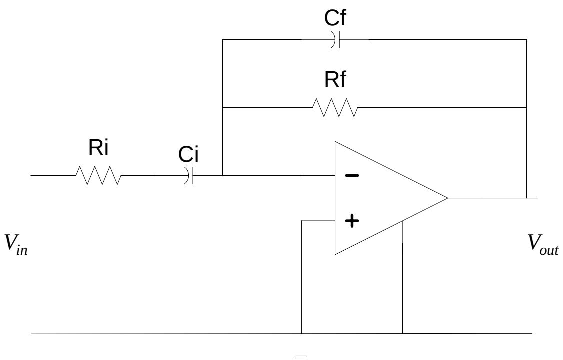
1. **Simplicity of the design**
2. **Non-Inverting Amplifier (positive Gain)**
3. **Replication of elements**

Limitations of Sallen-Key Filters:

1. **The Gain and Q are related**
2. ***Q* must be > ½, since *A* must be > 1**

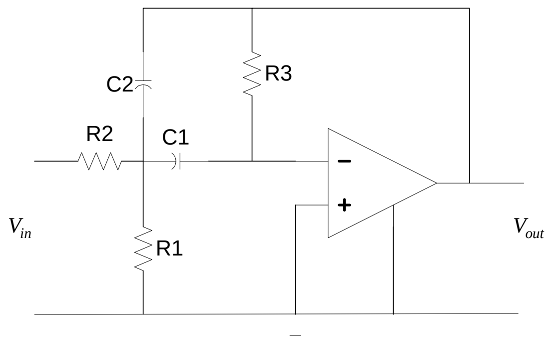
Other Active Filters

Band Pass 1:



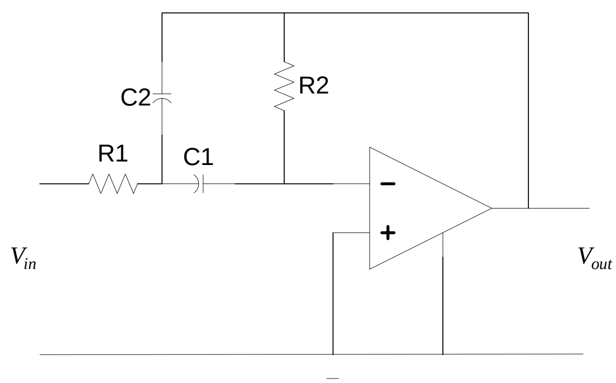
$$H(s) = -\frac{R_f}{R_i}\frac{\frac{1}{R_f C_f}s}{s^2 + \left(\frac{1}{R_f C_f} + \frac{1}{R_i C_i}\right)s + \frac{1}{R_i C_i R_f C_f}}$$

Band Pass 2:



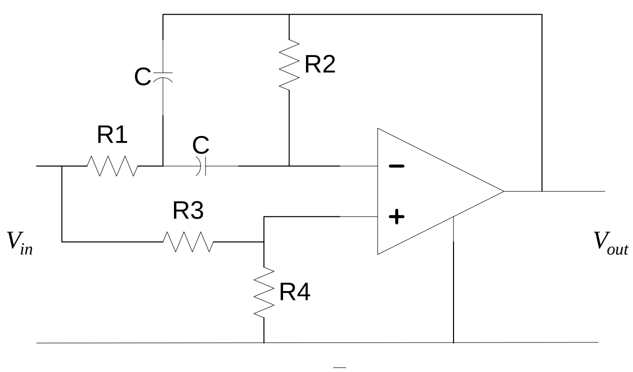
$$H(s) = \frac{-\frac{1}{R_2 C_2}s}{s^2 + \left(\frac{C_1 + C_2}{R_3 C_1 C_2}\right)s + \frac{1}{(R_1 \| R_2) R_3 C_1 C_2}}$$

Band Pass 3:



$$H(s) = \frac{-\frac{1}{R_1 C_2}s}{s^2 + \left(\frac{C_1 + C_2}{R_2 C_1 C_2}\right)s + \frac{1}{R_1 R_2 C_1 C_2}}$$

Band Reject 1:



$$H(s) = \frac{R_4}{R_3 + R_4}\frac{s^2 + s\left(\frac{2}{R_2 C} - \frac{R_3}{R_1 R_4 C}\right) + \frac{1}{C^2 R_1 R_2}}{s^2 + s\frac{2}{R_2 C} + \frac{1}{C^2 R_1 R_2}}$$

<u>*Other Active Filters*</u>

Properties & Design Hints

- **These amplifiers are "inverting amplifiers" (negative gain)**
- **BPF1 is restricted to *Q* > ½.**
- **BPF2 can have a *Q* < ½ if** $C_1 \neq C_2$**.**
- **Both gain and *Q* can be controlled with the circuit elements.**
- **BRF1 does not have a true zero on the imaginary axis unless** $\frac{R_3}{R_1 R_4} = \frac{2}{R_2}$**.**
- **A design may not require a true null, but a notch. The zero can be adjusted to control the "dip" in the response.**
- **Typical design: Specify the gain, *Q*, and resonant frequency, and then solve for the circuit elements.**
    - **Requires some assumptions for the values of *R*'s and *C*'s (problem is under-determined). Choose *R* to be large (> 1 k) when possible. Possibly choose relationships (such as** $C_1 = k \times C_2$**).**
    - **Equations for remaining elements can be non-linear.**
    - **Not all values of *Q*,** A_v**, and** ω_o **are necessarily possible.**
    - **Gain may not be as important as *Q* and resonant frequency if the amplifier is one stage of a system design.**