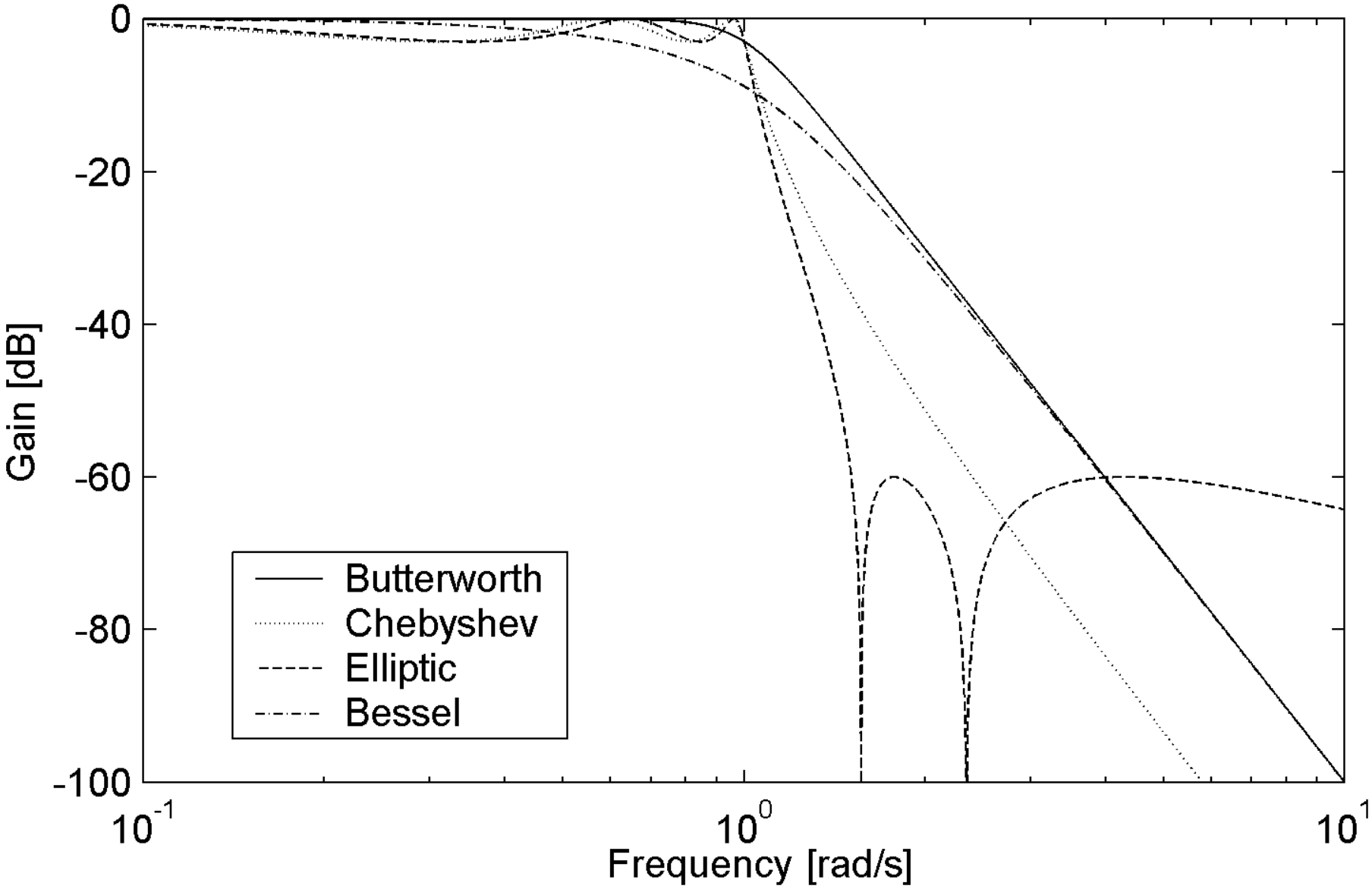
Faculty of Engineering

MEP 382: Design of Applied Measurement Systems

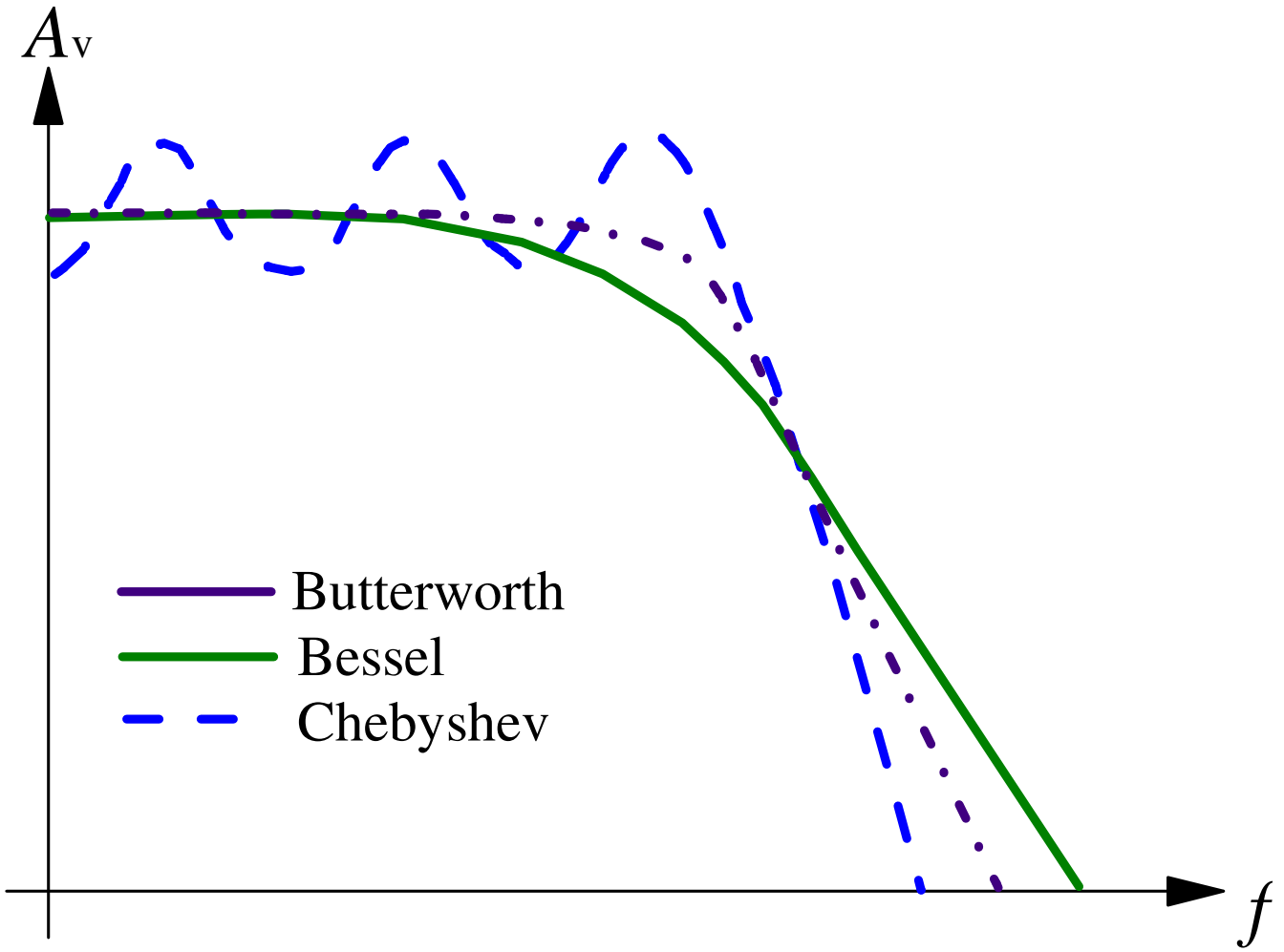
Lecture 9:
Active Filters

Real Filters

- The approximations to the ideal filter are the:
  - Butterworth filter
  - Chebyshev filter
  - Cauer (Elliptic) filter
  - Bessel filter

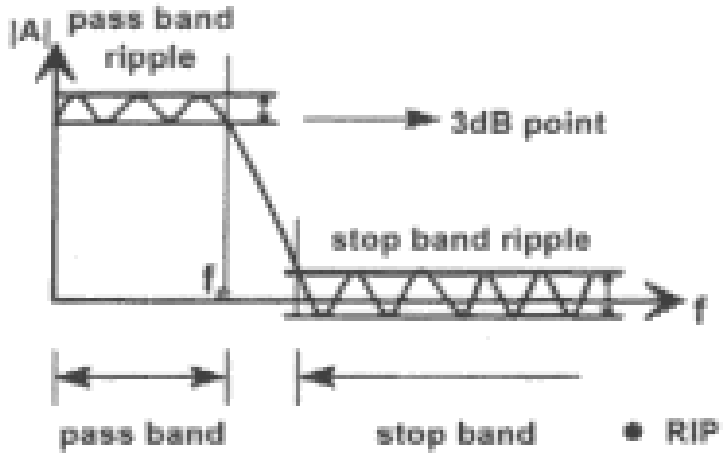

0
-20
-40
-60
-80
-100
Gain [dB]
10^{-1}
10^{0}
10^{1}
Frequency [rad/s]
Butterworth
Chebyshev
Elliptic
Bessel

Filter Response Characteristics



PERFORMANCE CRITERIA

AMPLITUDE RESPONSE



$20 \log_{10} |A|$ = Gain in dB

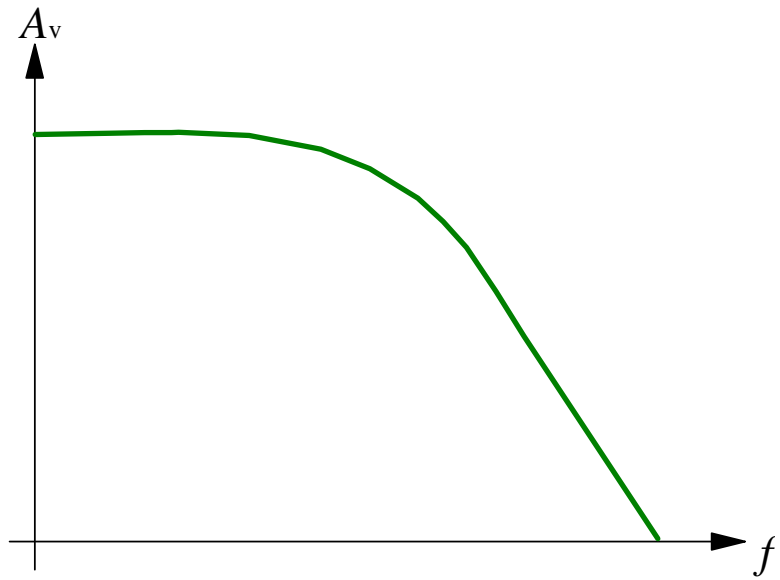
f_c = Cut-off Frequency

Gain at 3dB point (at f_c) = $\frac{|A|}{\sqrt{2}}$

- RIPPLE IN PASS BAND CAUSES NON-LINEARITY
- POSSIBLE TO DESIGN WITH NO RIPPLE
- RIPPLE IN STOP BAND IS LESS IMPORTANT
- FALL OFF dB / Decade (Gain in dB / Decade of f)
- STOP BAND ATTENUATES (SAY - 40dB)

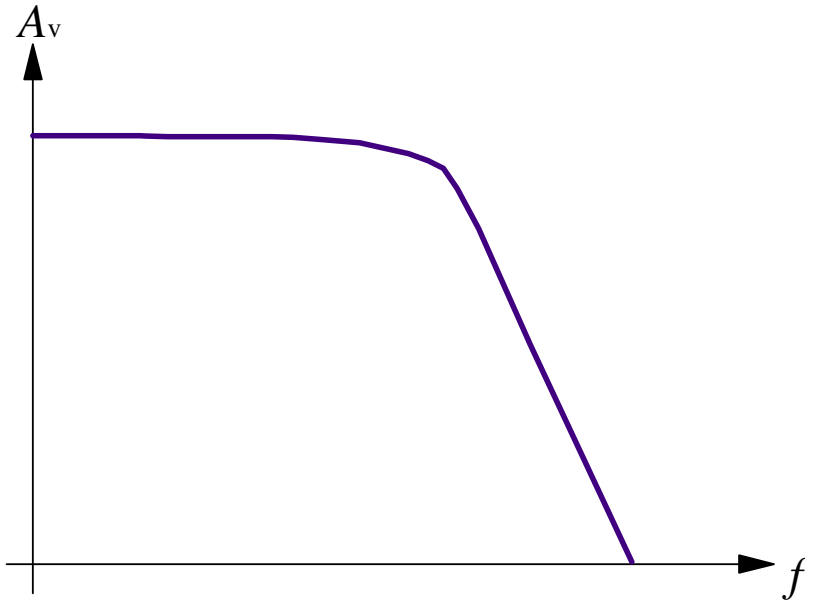
Bessel Characteristic

- Flat response in the passband.
- Role-off rate less than *20dB*/decade/pole.
- Phase response is linear.
- Used for filtering pulse waveforms without distorting the shape of the waveform.



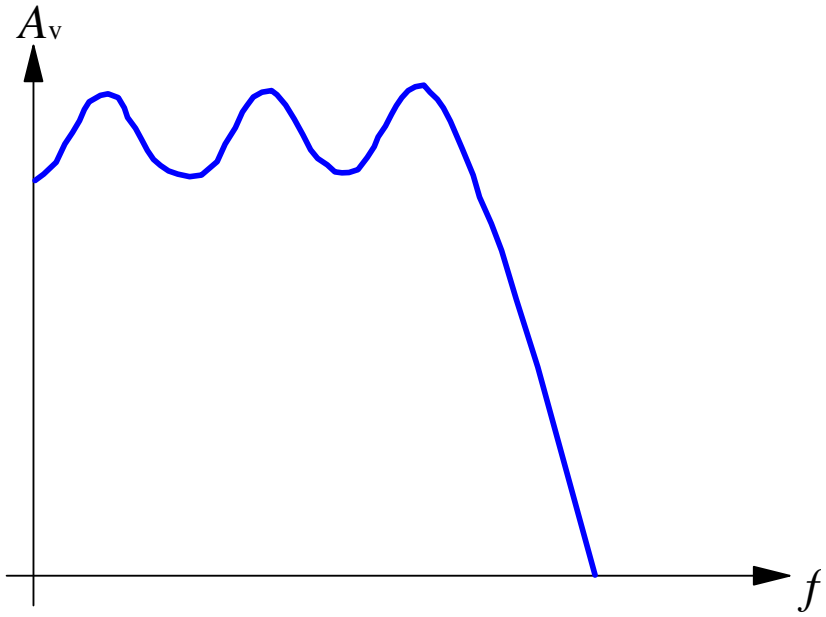
Butterworth Characteristic

- Very flat amplitude, $A_{v(dB)}$, response in the passband.
- Role-off rate is *20dB*/decade/pole.
- Phase response is not linear.
- Used when all frequencies in the passband must have the same gain.
- Often referred to as a *maximally flat response*.



Chebyshev Characteristic

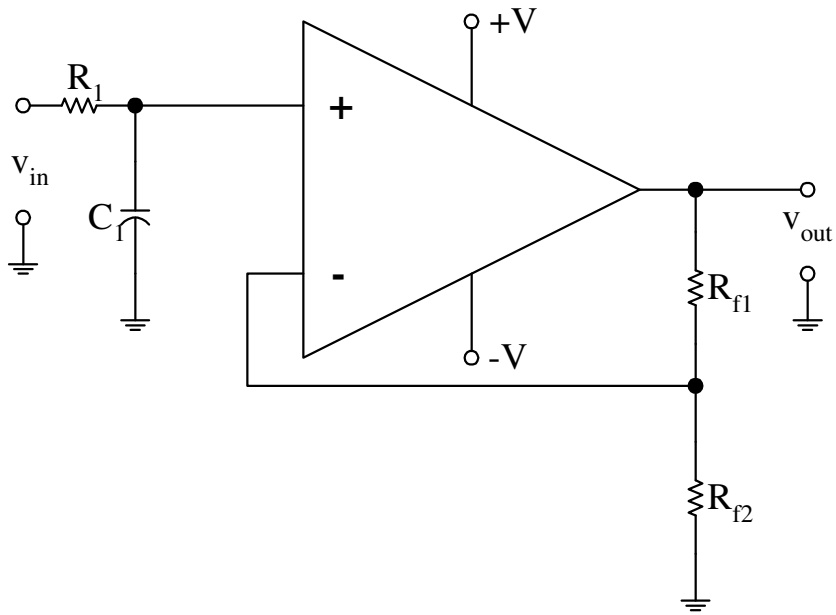
- Overshoot or ripples in the passband.
- Role-off rate greater than *20dB*/decade/pole.
- Phase response is not linear - worse than Butterworth.
- Used when a rapid roll-off is required.



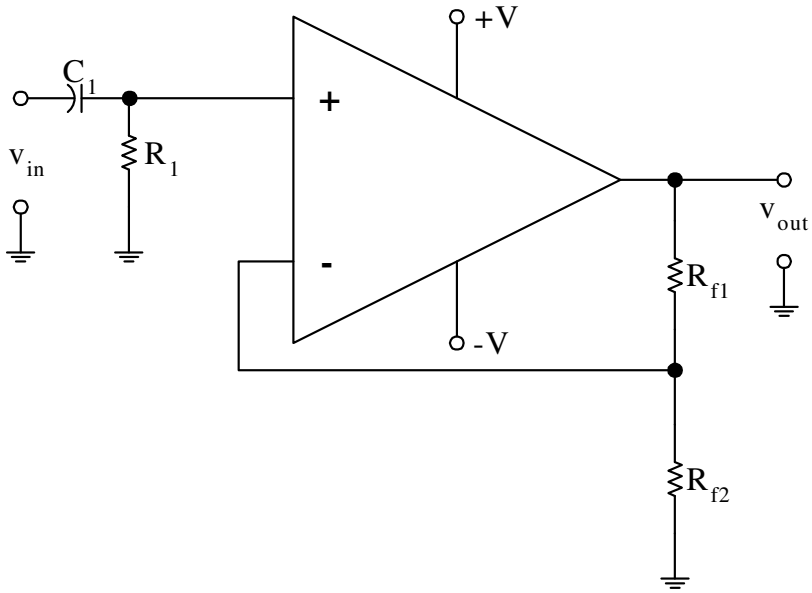
Active Filter Implementations

- Cascading
- Multiple Feedback topology
- Biquad topology
- Sallen-Key topology

Single-Pole Low/High-Pass Filter

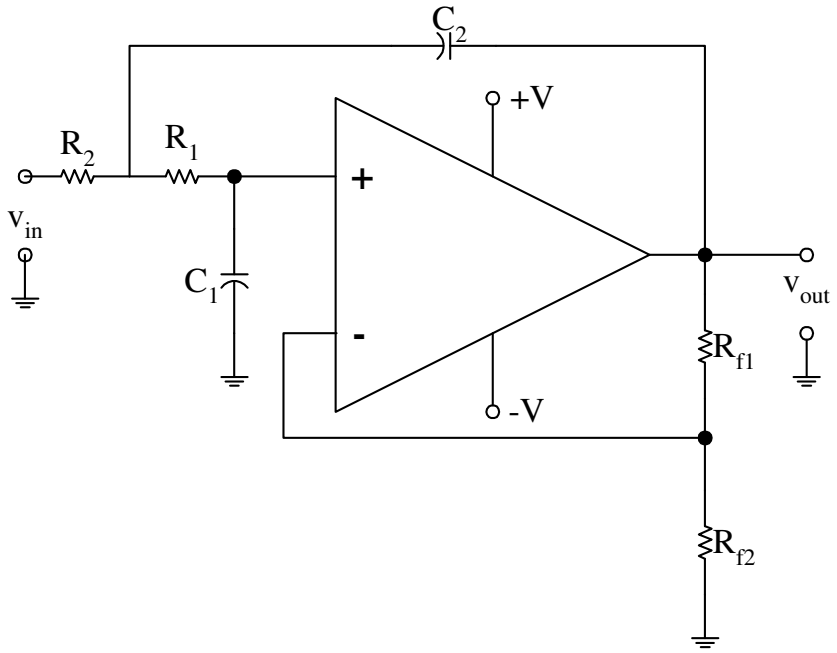


Low Pass Filter

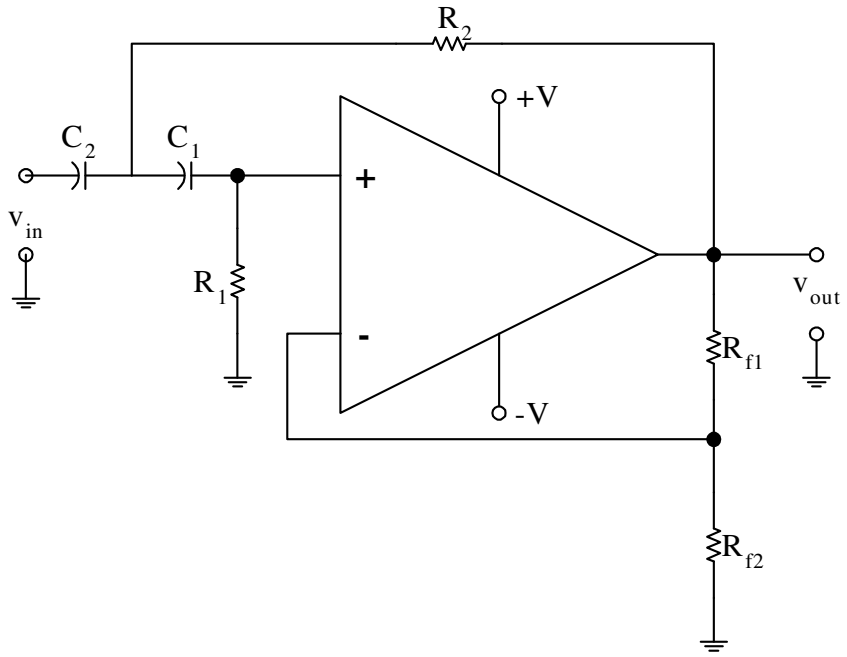


High Pass Filter

Two-Pole (Sallen-Key) Filters

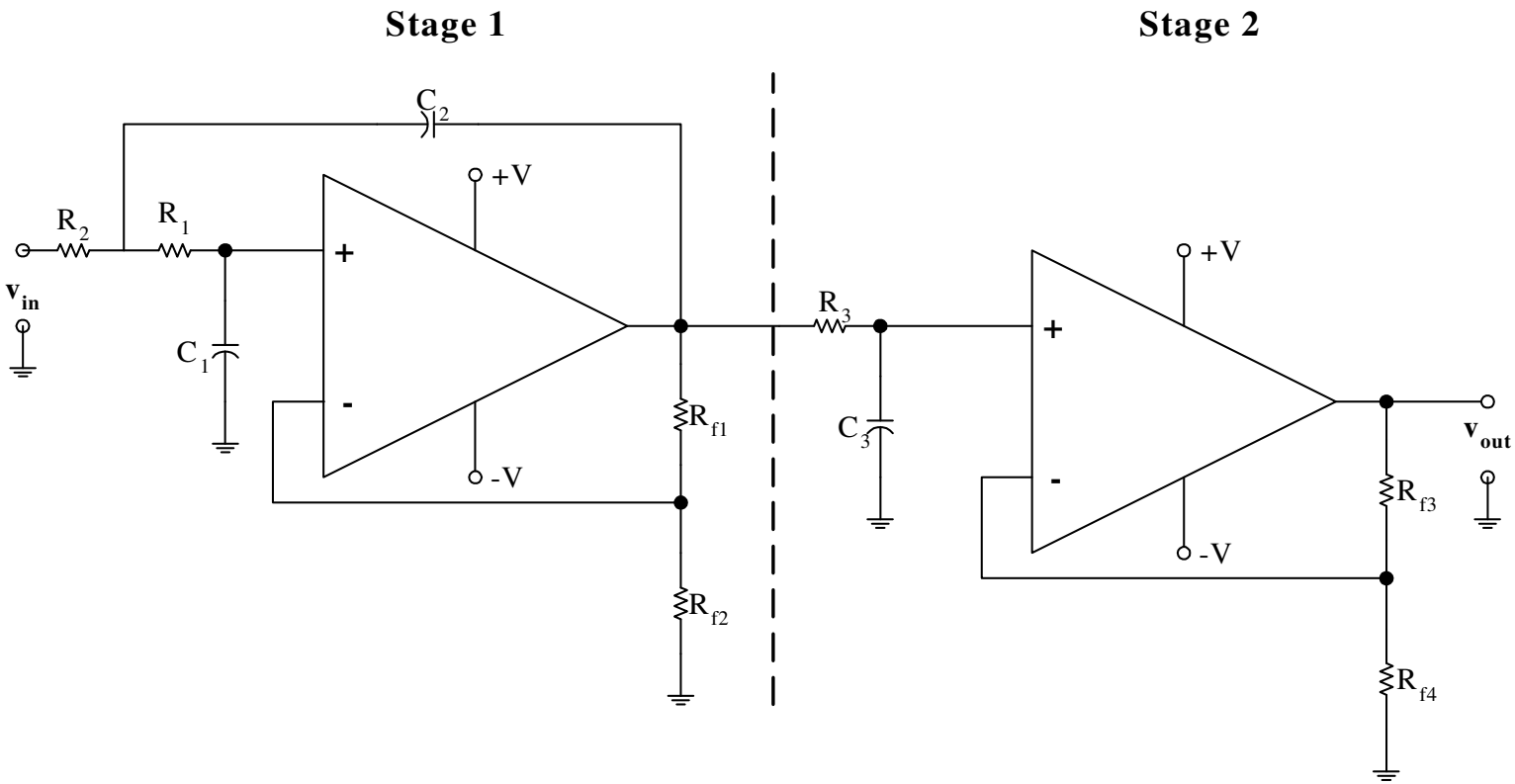


Low Pass Filter

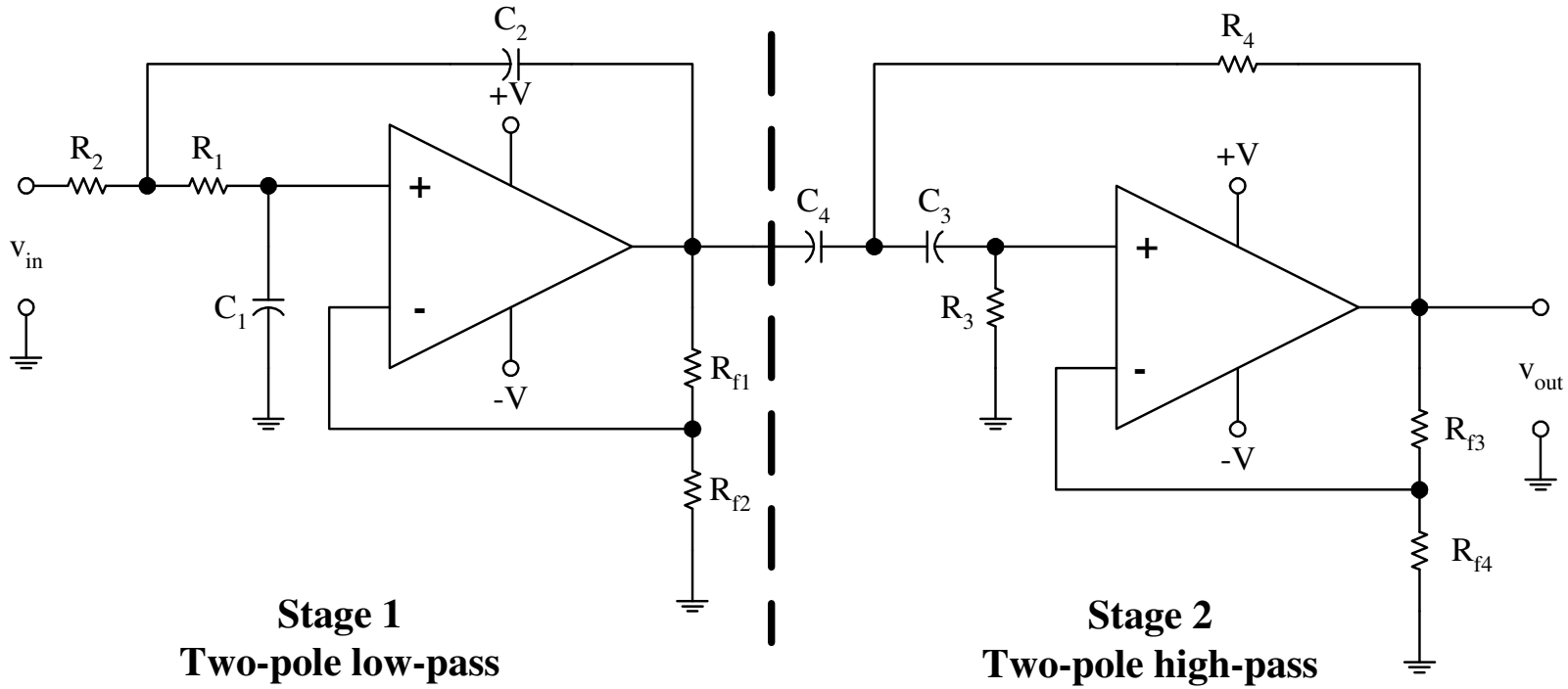


High Pass Filter

Three-Pole Low-Pass Filter

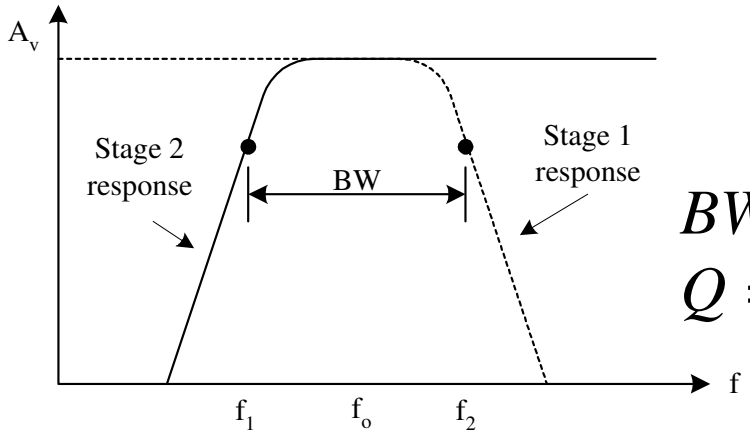


Two-Stage Band-Pass Filter



Stage 1
Two-pole low-pass

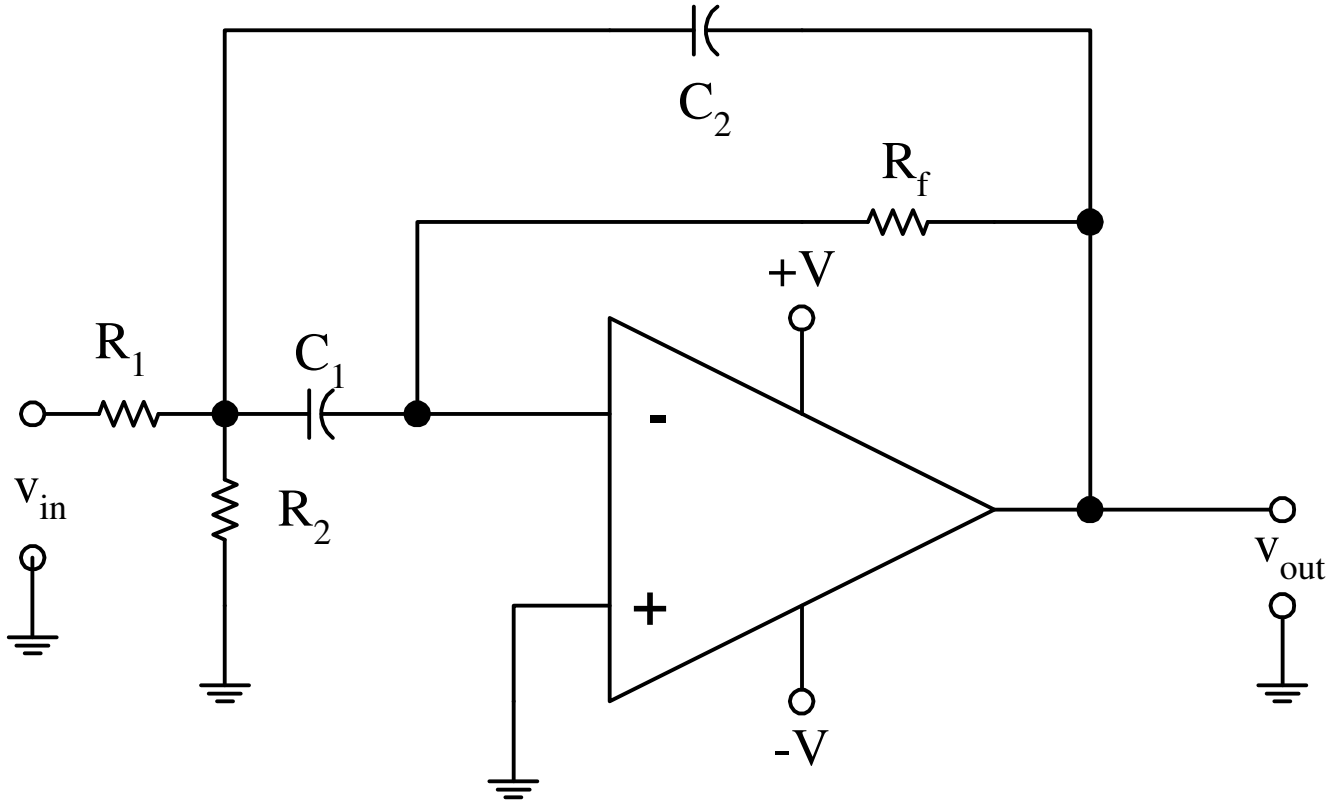
Stage 2
Two-pole high-pass



$$BW = f_2 - f_1$$

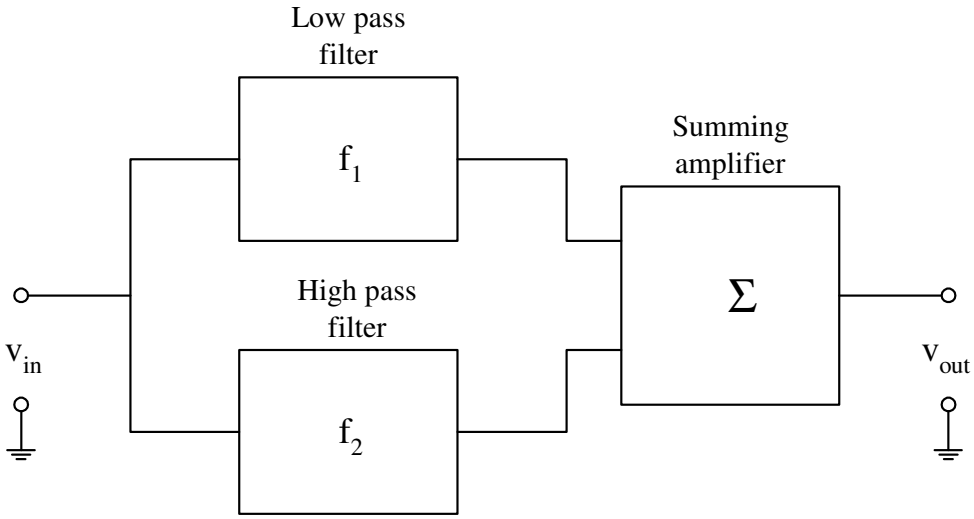
$$Q = f_0 / BW$$

Multiple-Feedback Band-Pass Filter

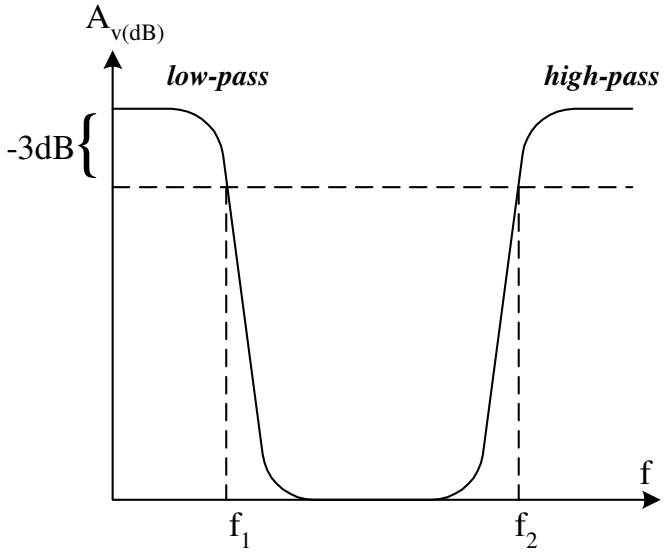


Band-Stop (Notch) Filter

The notch filter is designed to block all frequencies that fall within its bandwidth. The circuit is made up of a ***high pass filter***, a ***low-pass filter*** and a ***summing amplifier***. The summing amplifier will have an output that is equal to the sum of the filter output voltages.

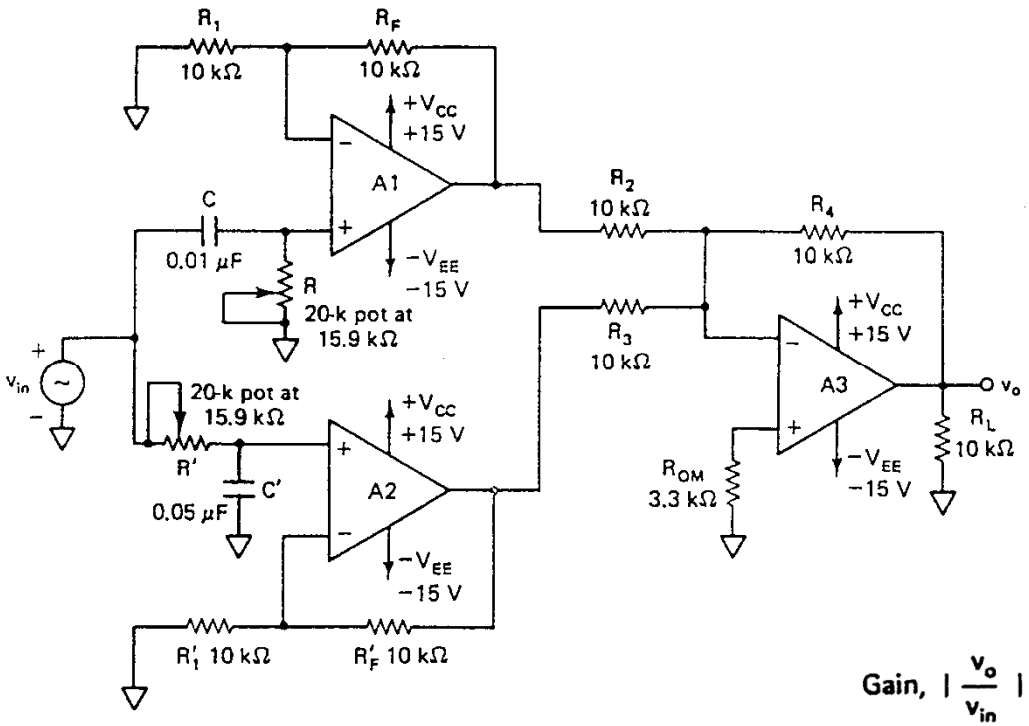


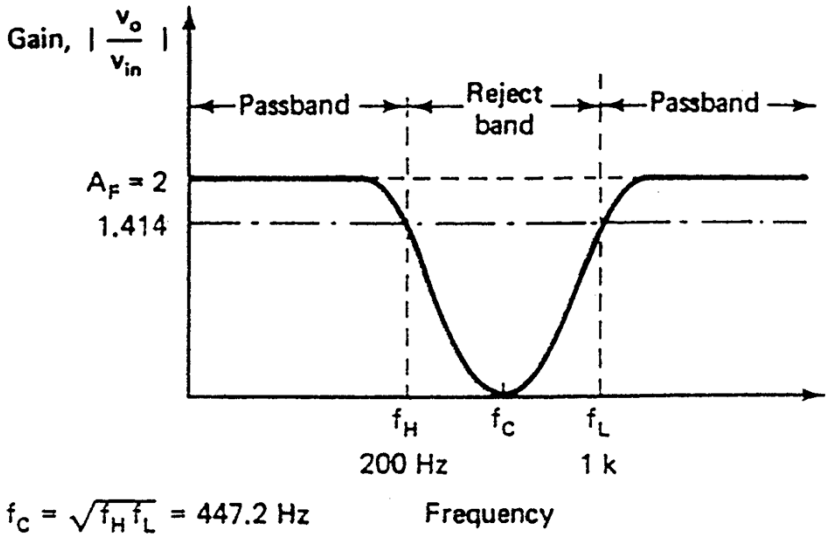
Block diagram



Frequency response

Notch filter





$f_C = \sqrt{f_H f_L} = 447.2$ Hz