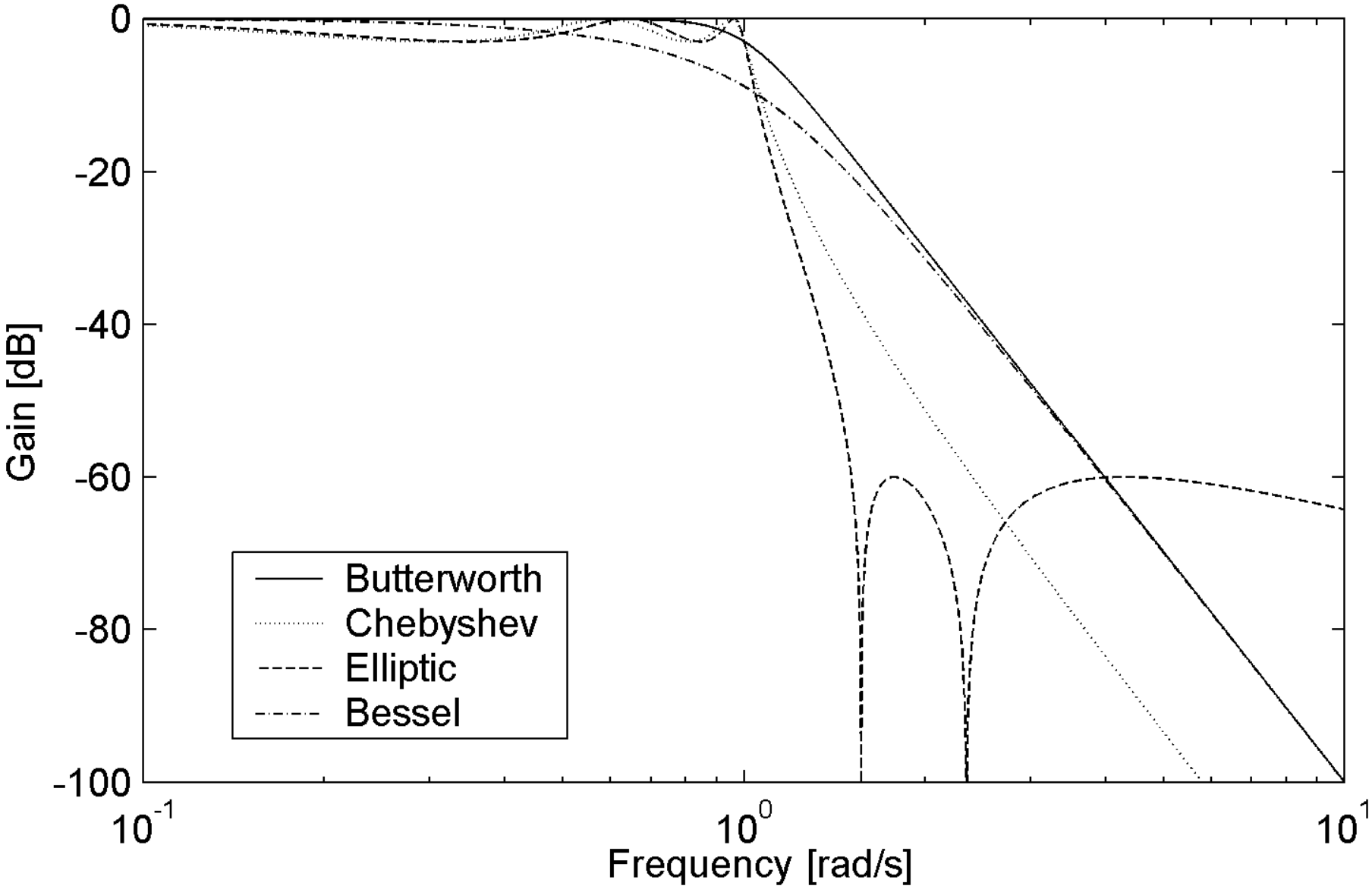

Faculty of Engineering

## MCT242: Electronic Instrumentation

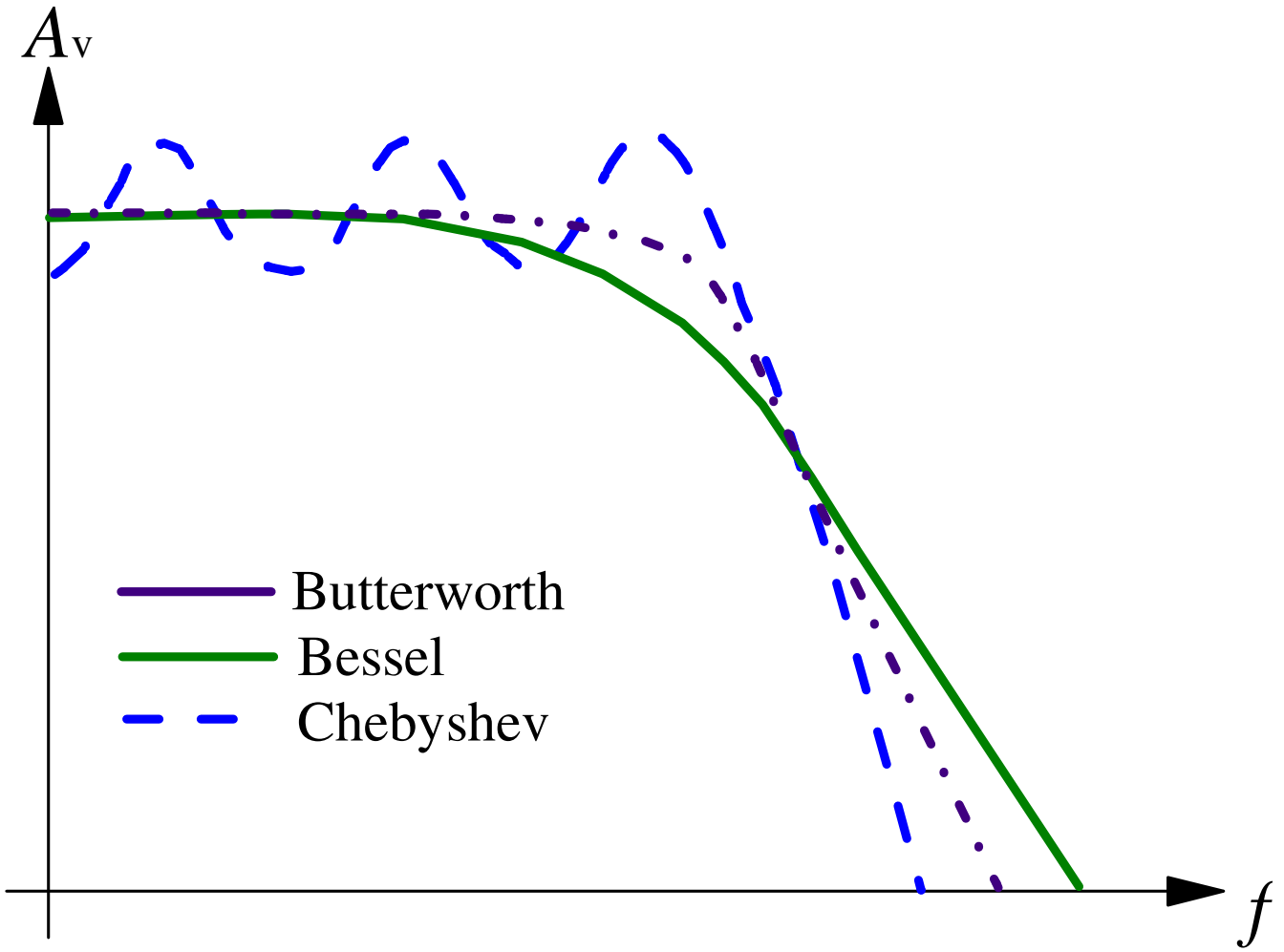
# Lecture 8:
# Active Filters

# Real Filters

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

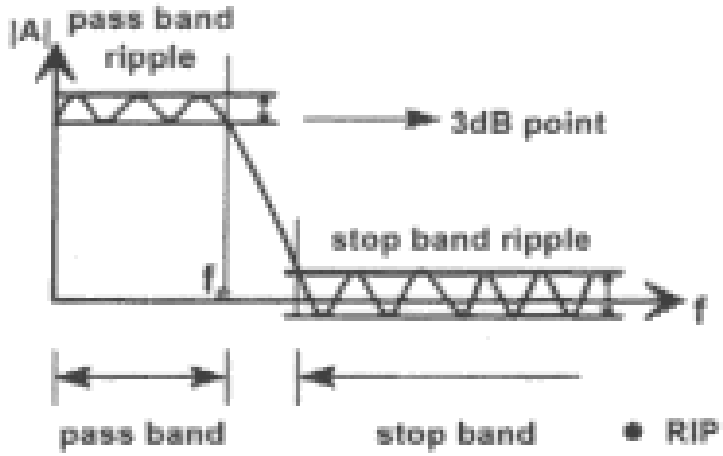

0
-20
-40
-60
-80
-100
Gain [dB]
$10^{-1}$
$10^{0}$
$10^{1}$
Frequency [rad/s]
Butterworth
Chebyshev
Elliptic
Bessel

# Filter Response Characteristics



# PERFORMANCE CRITERIA

## AMPLITUDE RESPONSE




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

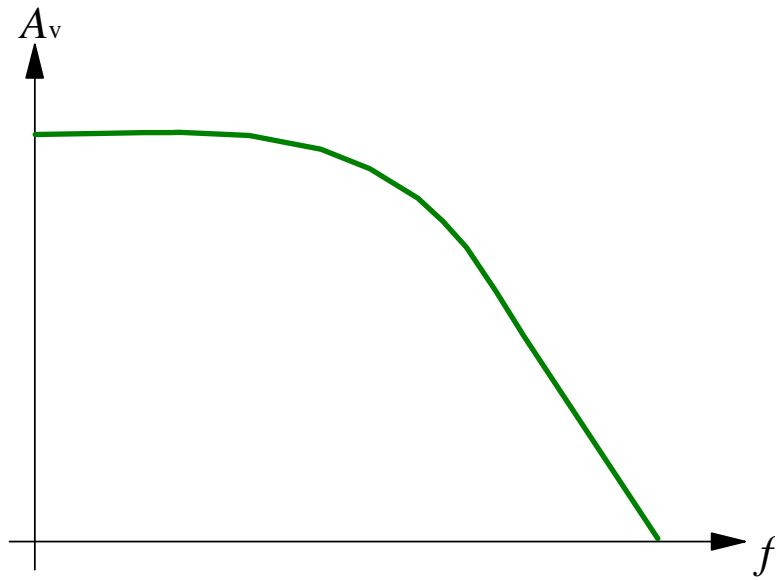
$f_c$ = Cut-off Frequency

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)

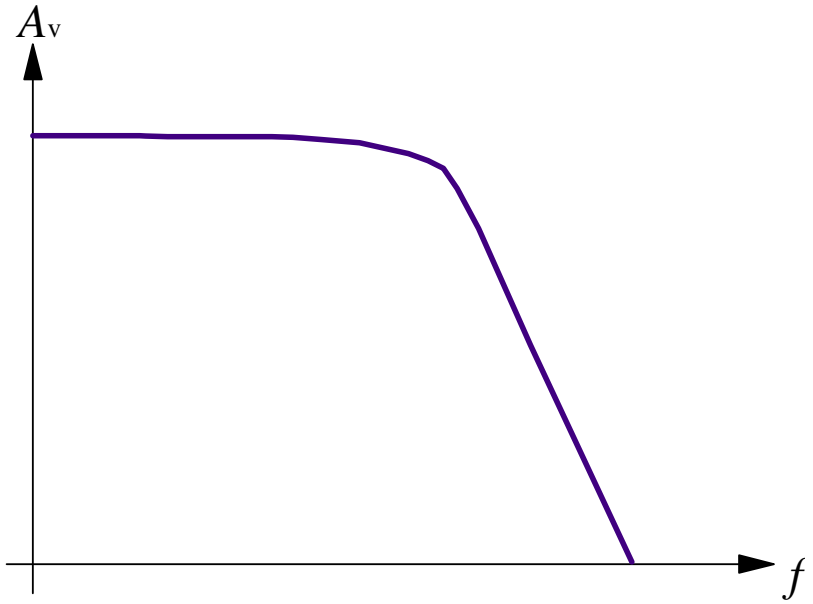
# Bessel Characteristic

- 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.



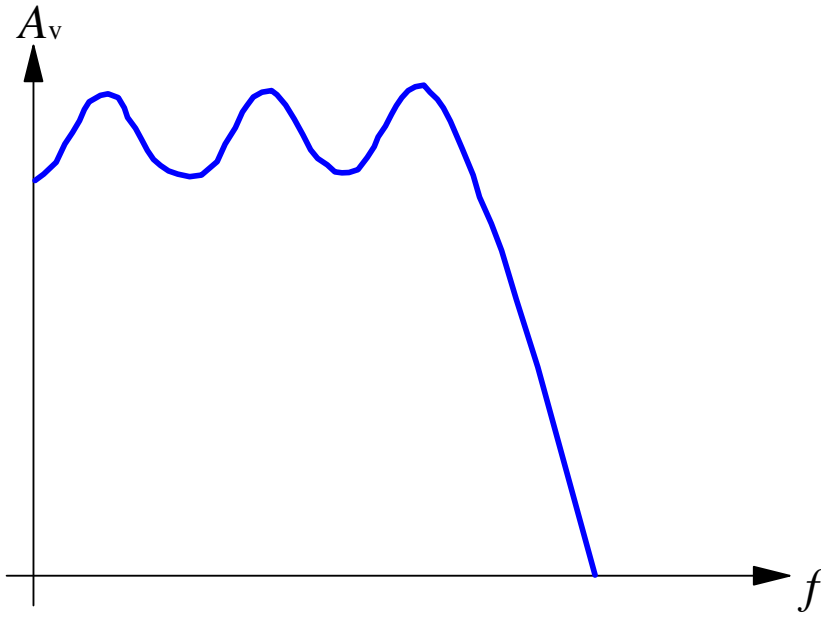
# Butterworth Characteristic

- 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

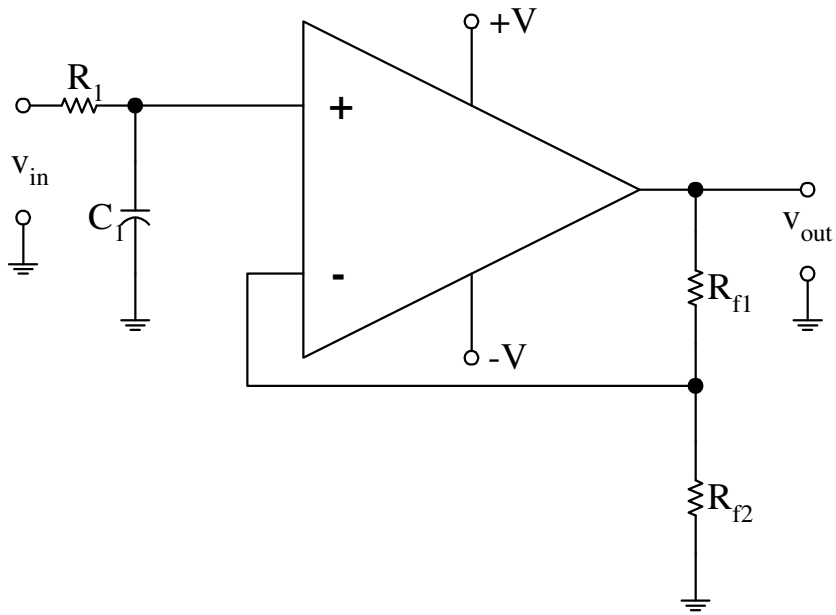
- Overshoot or ripples in the passband.
- Role-off rate greater than *20dB*/decade/pole.
- Phase response is not linear - worse than Butterworth.
- Used when a rapid roll-off is required.



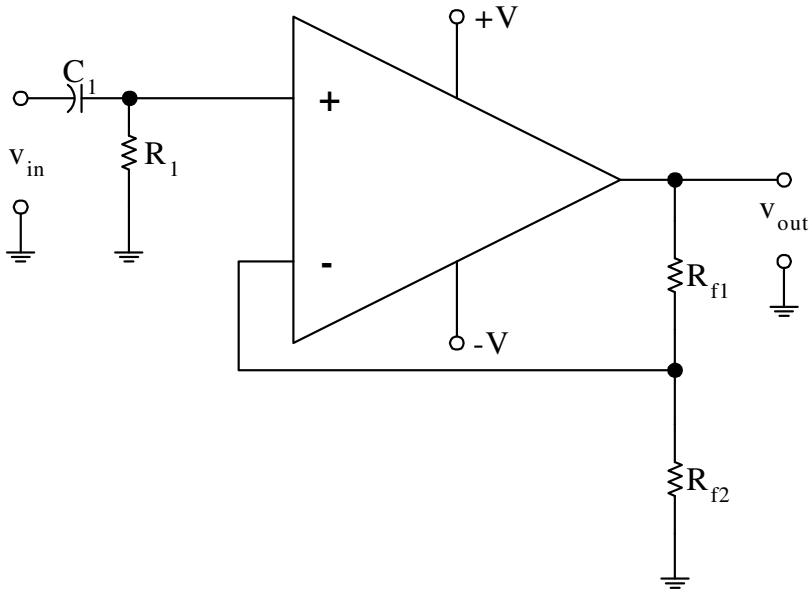
# Active Filter Implementations

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

# Single-Pole Low/High-Pass Filter

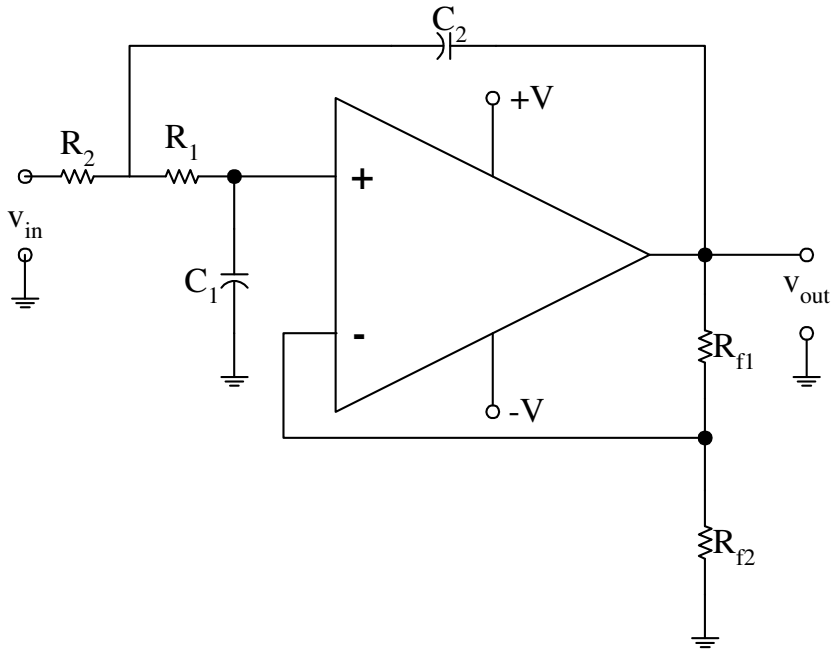



Low Pass Filter

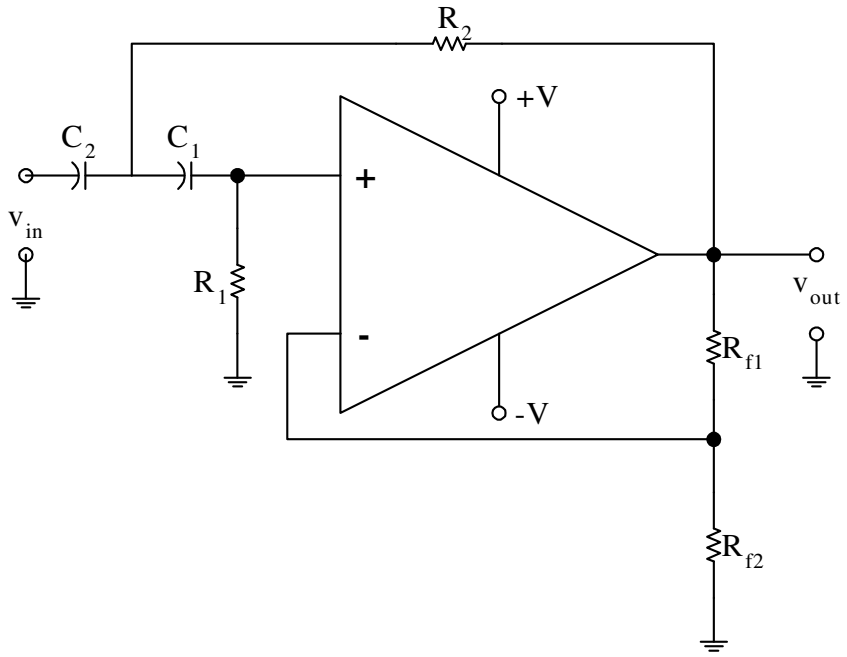



High Pass Filter

# Two-Pole (Sallen-Key) Filters

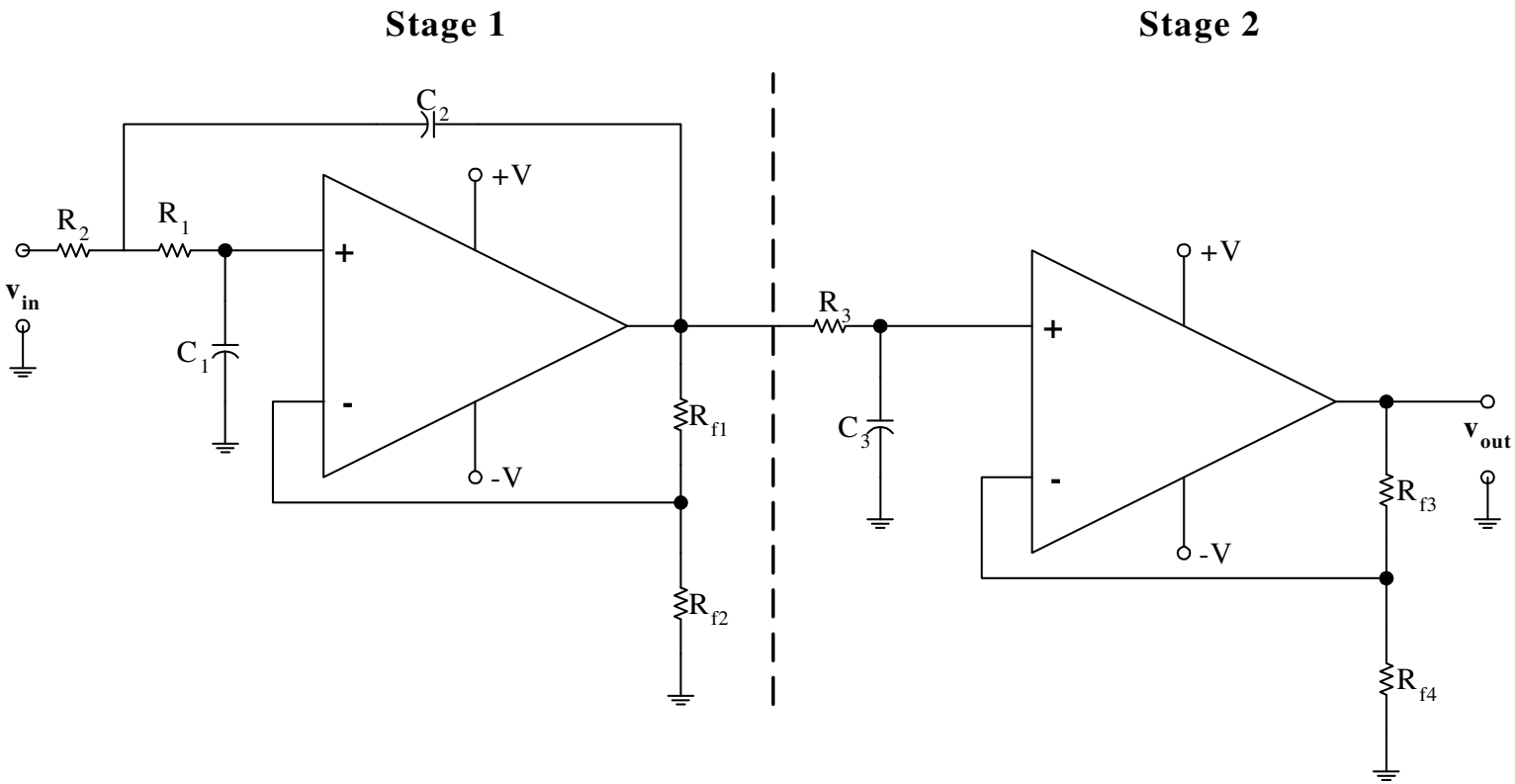



Low Pass Filter

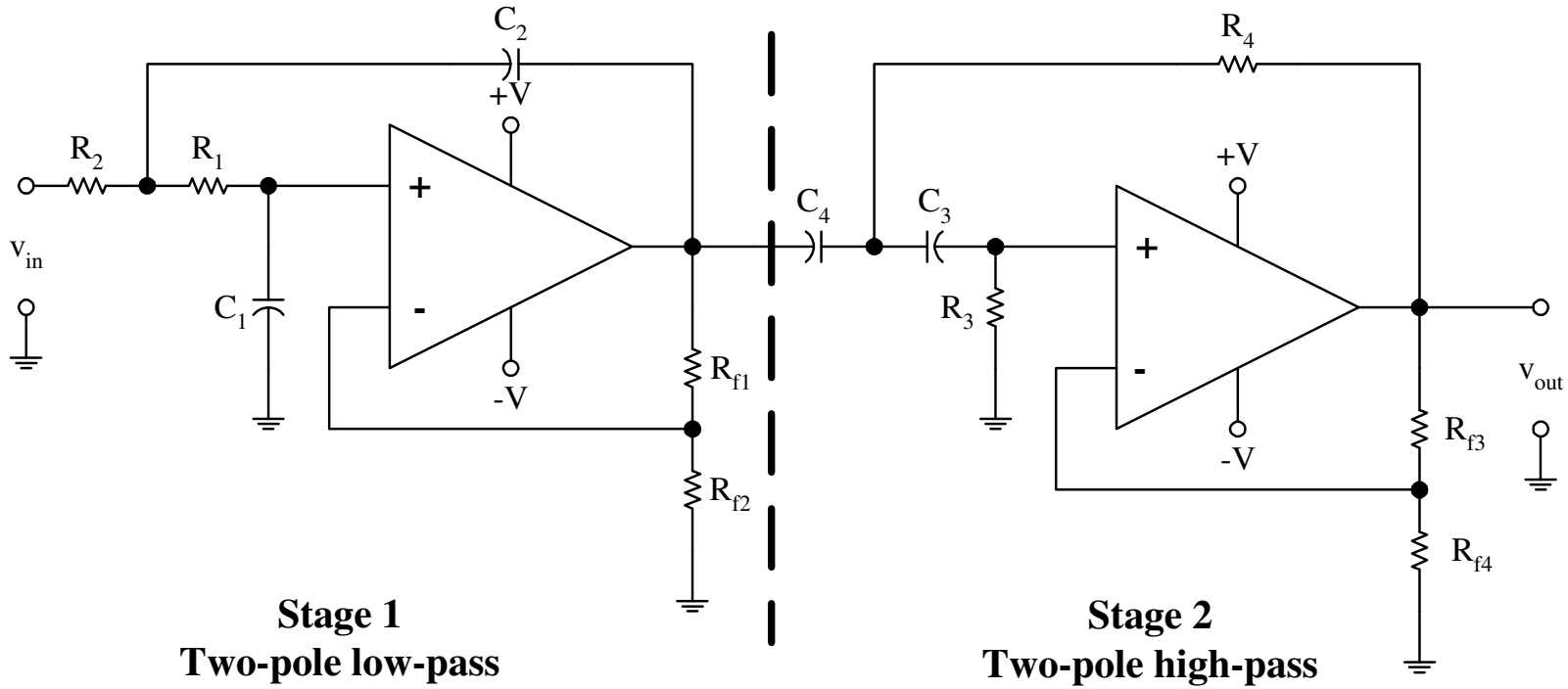



High Pass Filter

# Three-Pole Low-Pass Filter

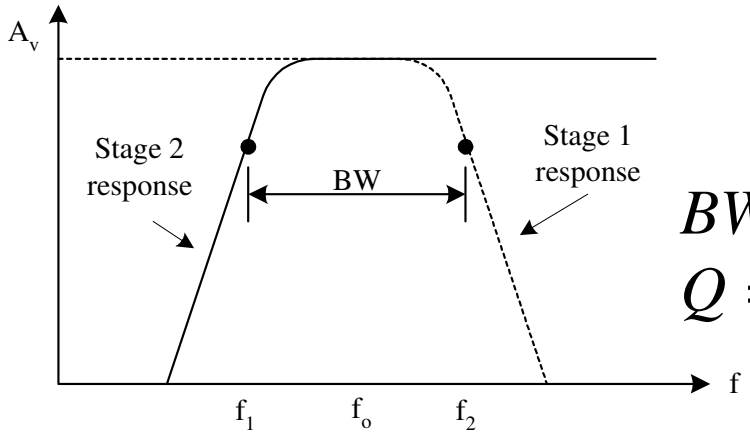


# Two-Stage Band-Pass Filter




**Stage 1**
**Two-pole low-pass**

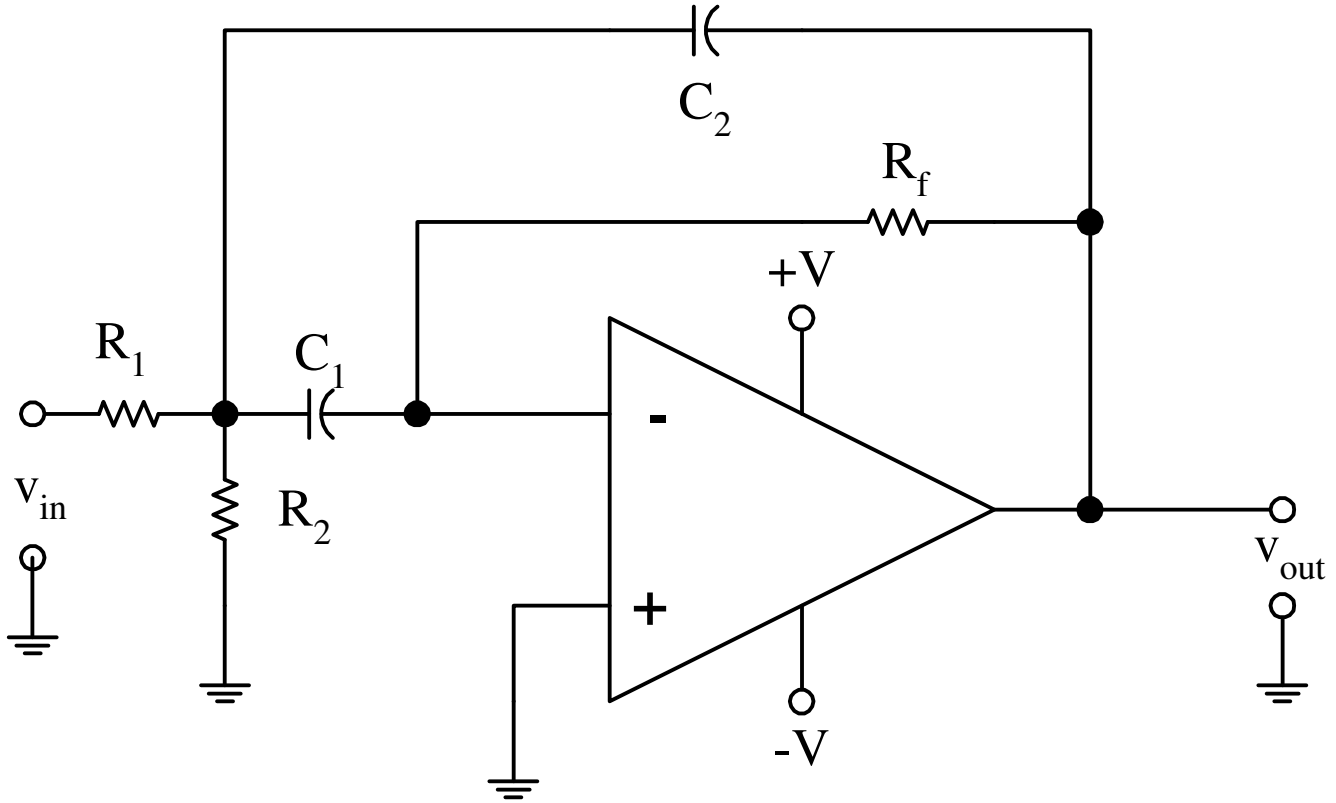
**Stage 2**
**Two-pole high-pass**




$$BW = f_2 - f_1$$

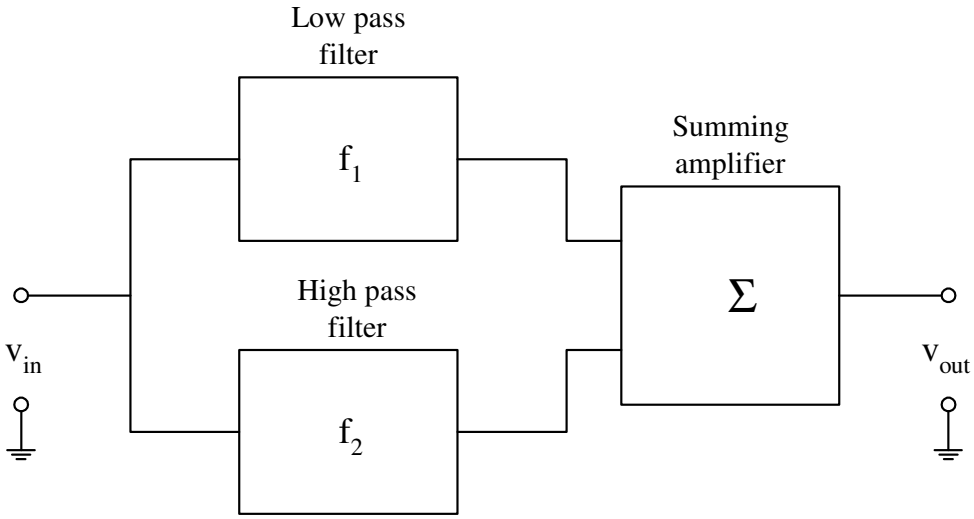
$$Q = f_0 / BW$$

# Multiple-Feedback Band-Pass Filter

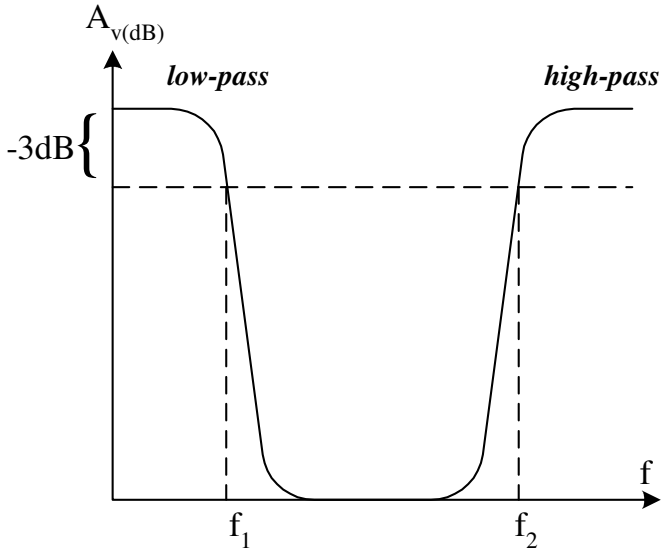


# Band-Stop (Notch) Filter

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.

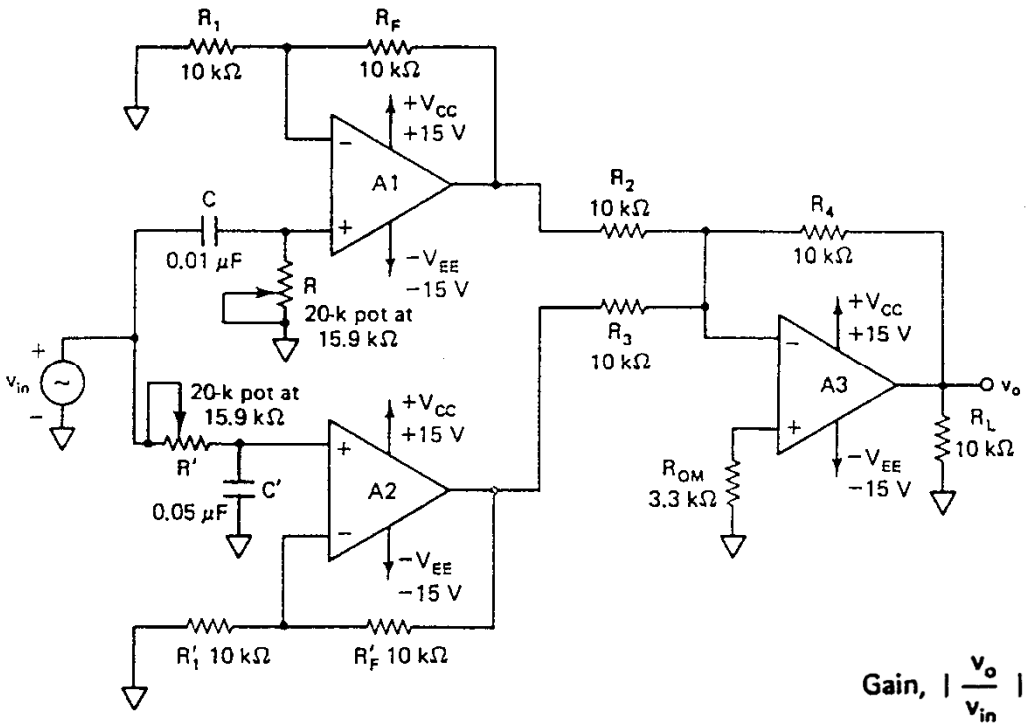


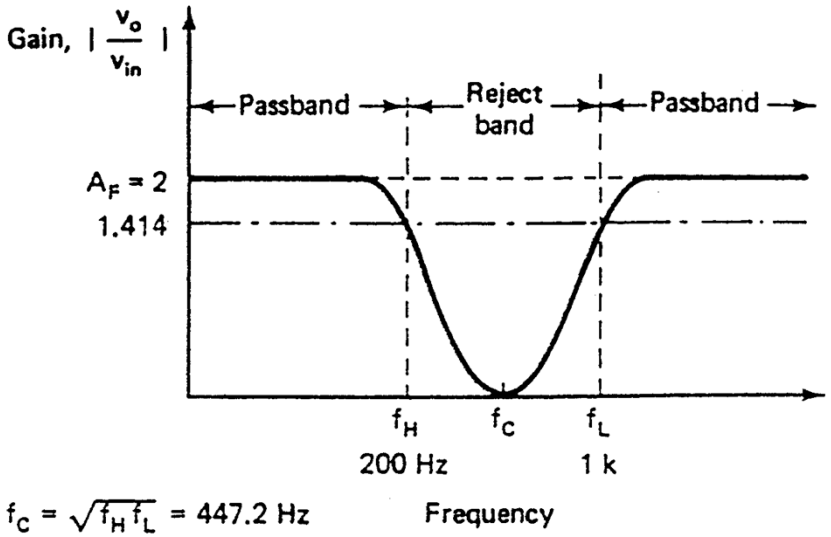

Block diagram




Frequency response

# Notch filter




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