Lab 9: Active Filter Circuits

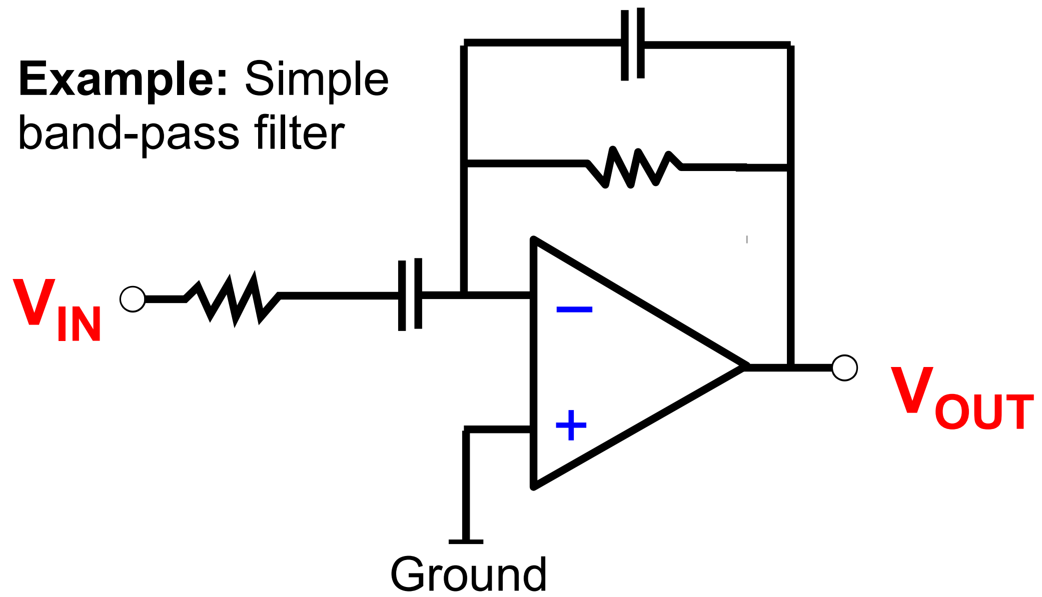
Active Filters

Frequency-dependent transfer function $G(\omega) = V_{OUT}/V_{IN}$

Active: Supply current to transistors, op-amps

Passive: Only resistors, capacitors, inductors, diodes, etc (earlier labs)

Example: Simple band-pass filter

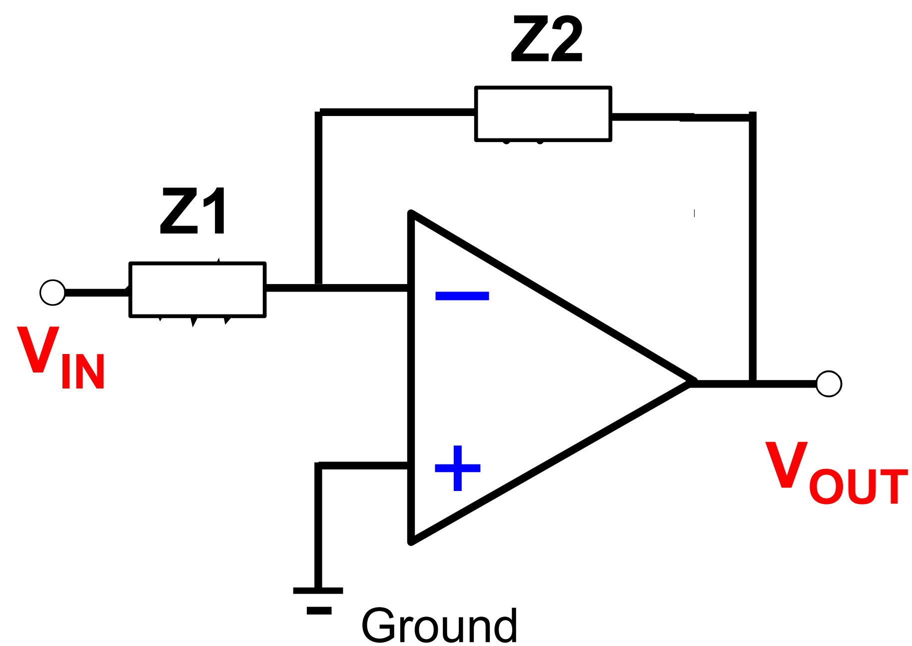


Advantages of active filtering over passive filtering
* Compensate for filter loss with amplification
* Performance nearly immune from influence of input/output circuits
* Don't need bulky, expensive inductors

Disadvantages
* Consumes power
* Can introduce electrical noise

Review of ideal Op-Amp

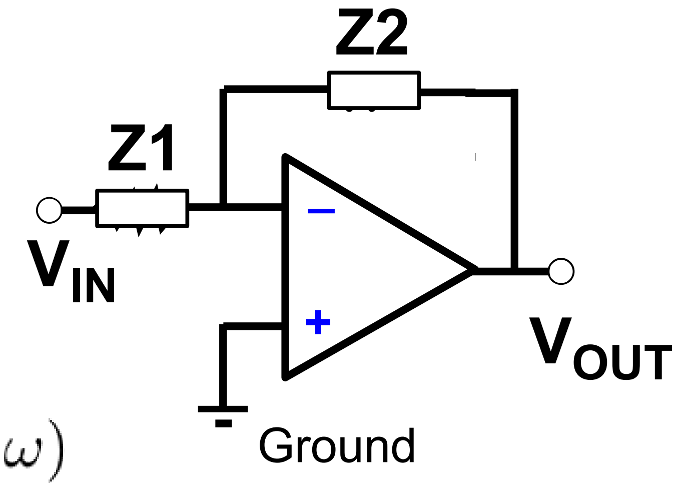
Very high input impedance
Negligible current flows into device
Inverting input (–)
Non-inverting input (+)
Extremely high amplification
Clever use of feedback



Inverting amplifier

$$\frac{V_{OUT}}{V_{IN}} = -\frac{Z2}{Z1}$$

Poles and Zeroes



$$\frac{V_{OUT}(\omega)}{V_{IN}(\omega)} = -\frac{Z_2(\omega)}{Z_1(\omega)} = G(\omega) = \frac{N(\omega)}{D(\omega)}$$

$$\text{Numerator: } N(\omega) = (\omega_{N1} + j\omega)(\omega_{N2} + j\omega) \times \ldots (\omega_{Nm} + j\omega)$$

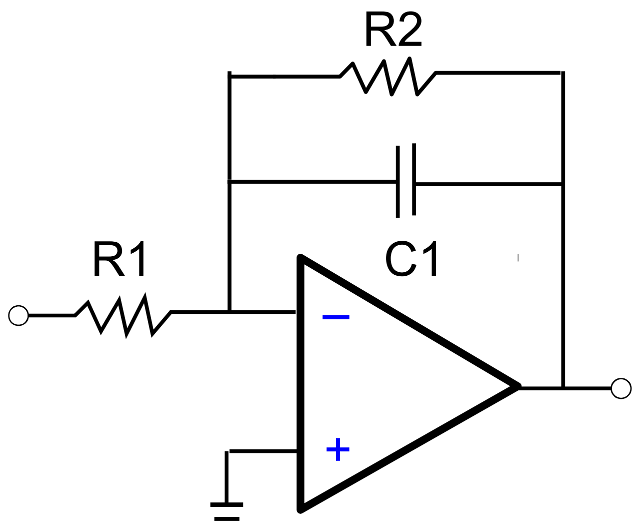
$$\text{Denominator: } D(\omega) = (\omega_{D1} + j\omega)(\omega_{D2} + j\omega) \times \ldots (\omega_{Dm'} + j\omega)$$

$$m \leq m'$$

Zeroes: Frequencies (ω_N) that make the numerator zero

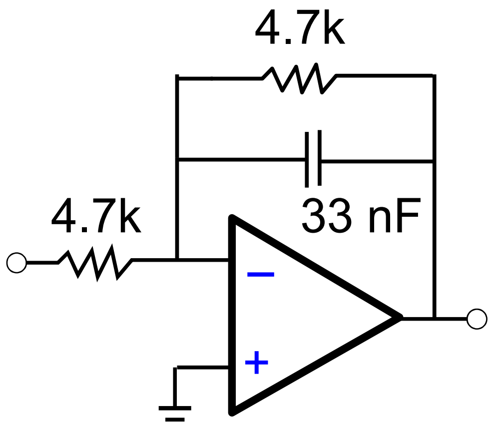
Poles: Frequencies (ω_D) that make the denominator zero

Example: Low-pass filter



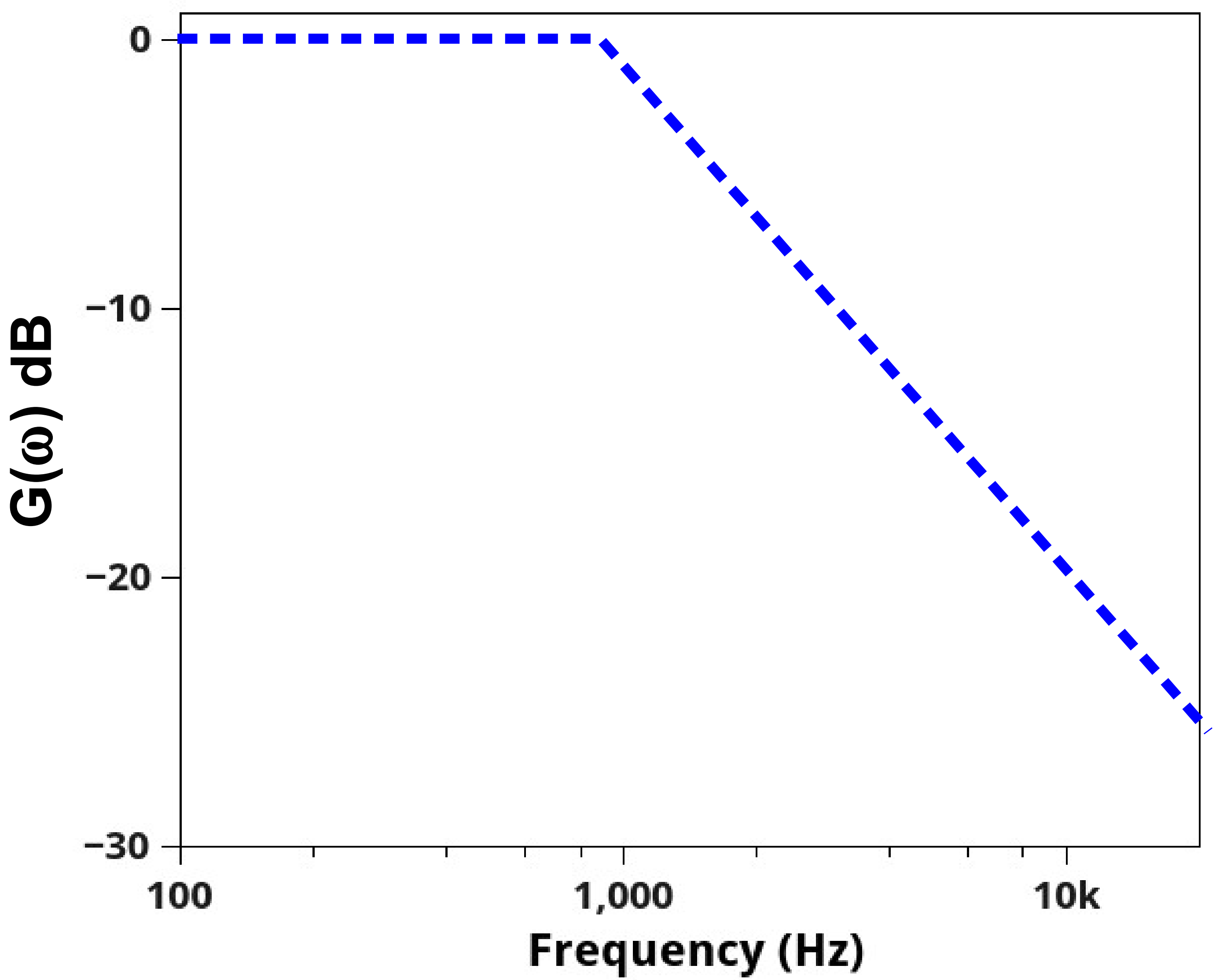
$$\frac{V_{OUT}}{V_{IN}} = -\frac{R2}{R1}\left(\frac{1}{1 + j\omega R2\ C1}\right)$$

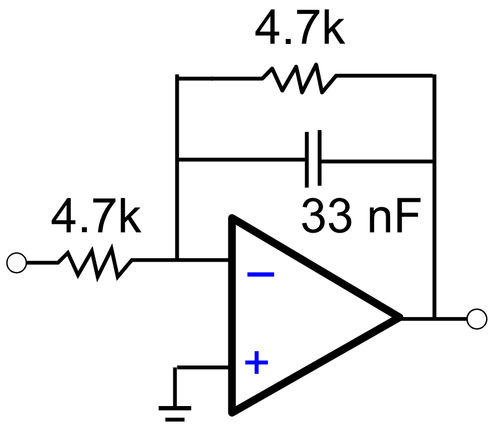
Pole in denominator



1-pole: 1 kHz

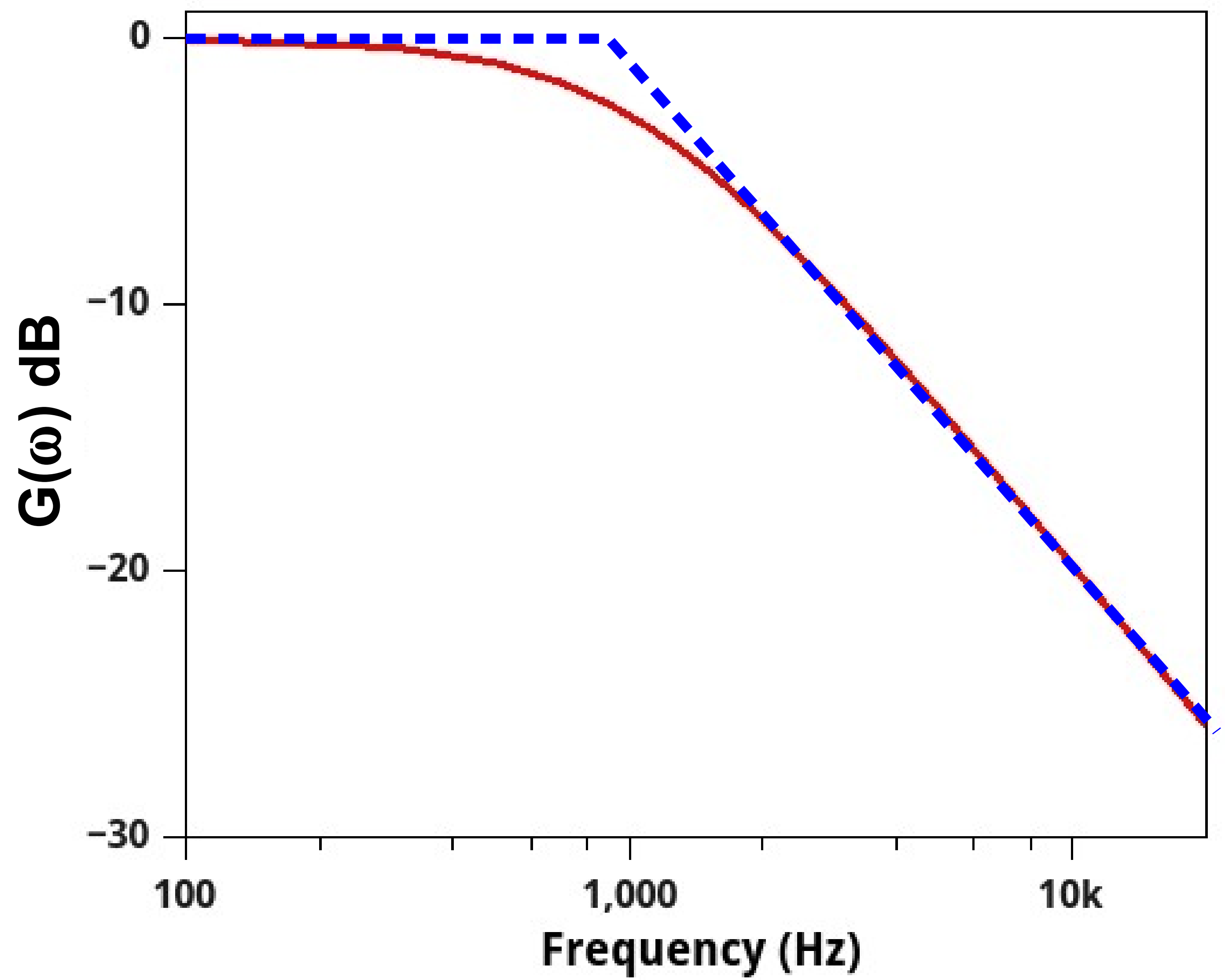
Pole at 1 kHz: –20 dB/decade



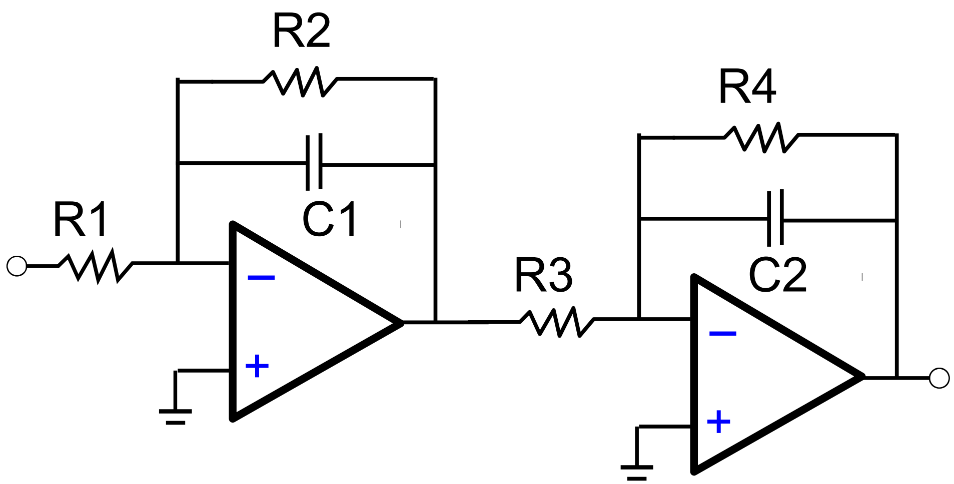


1-pole: 1 kHz

Red curve: Full-model calculation

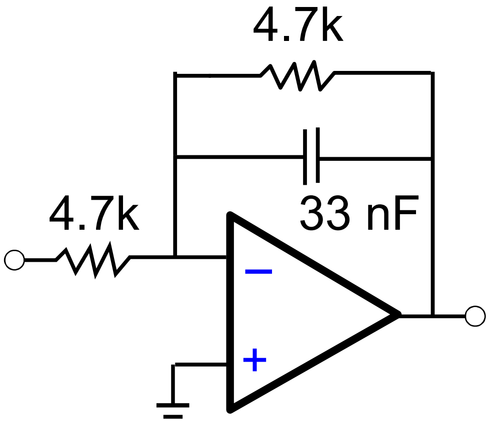


Example: Low-pass filter

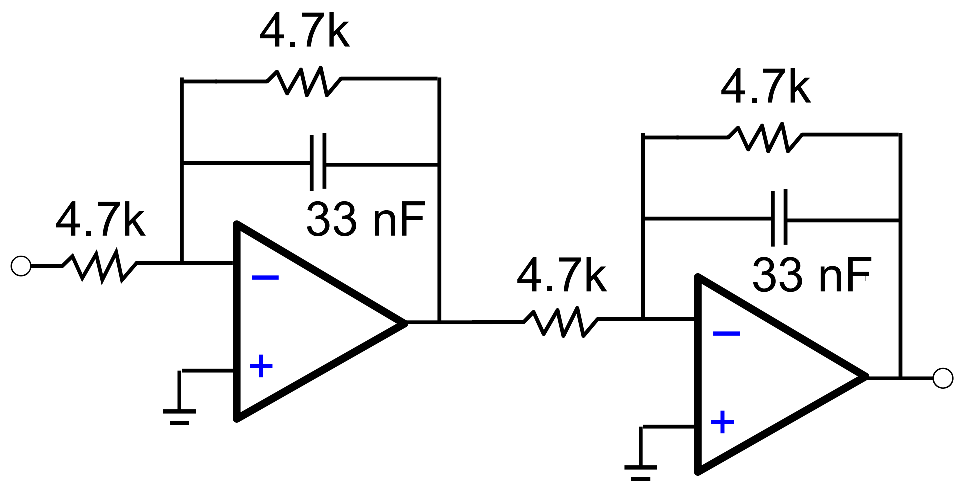


$$\frac{V_{OUT}}{V_{IN}} = \frac{R2}{R1}\left(\underbrace{\frac{1}{1+j\omega R2\ C1}}_{\text{1st pole}}\right)\frac{R4}{R3}\left(\underbrace{\frac{1}{1+j\omega R4\ C2}}_{\text{2nd pole}}\right)$$

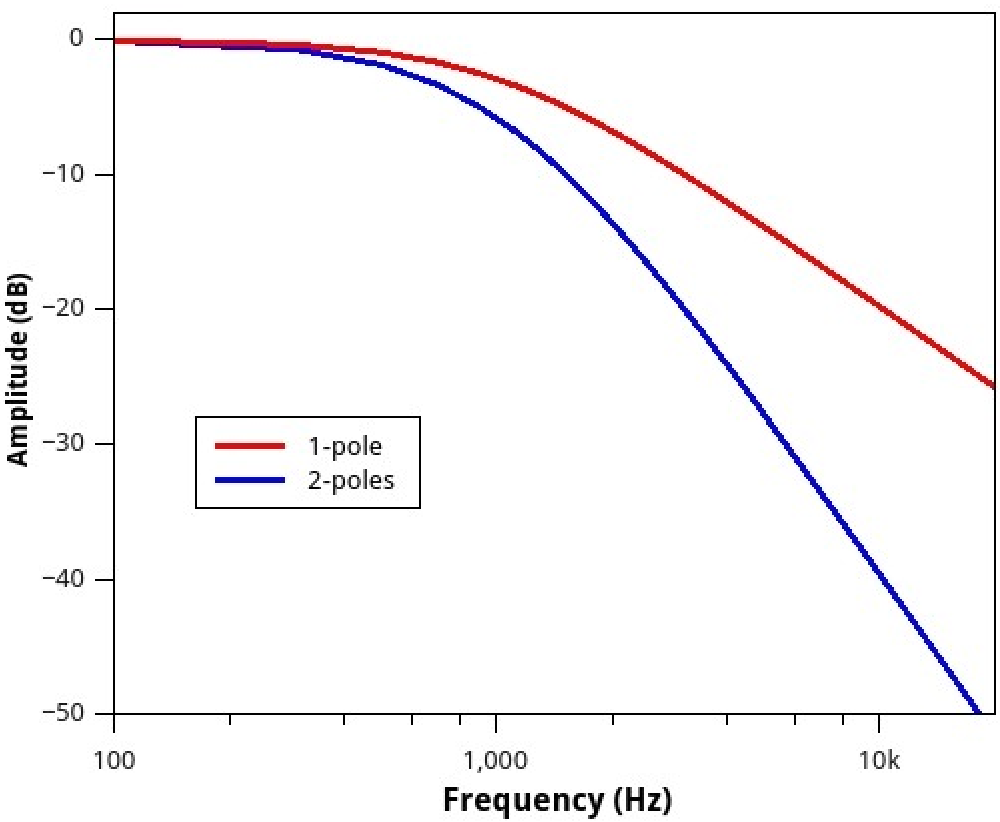
1st pole **2nd pole**

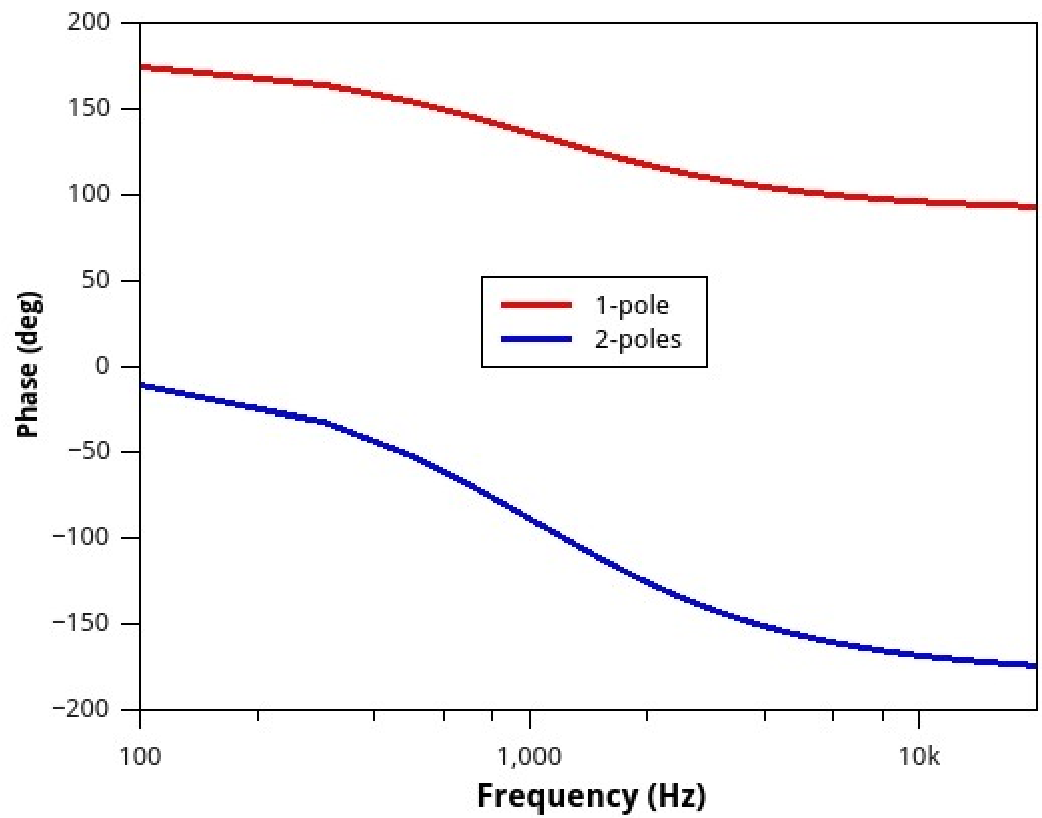


1-pole: 1 kHz

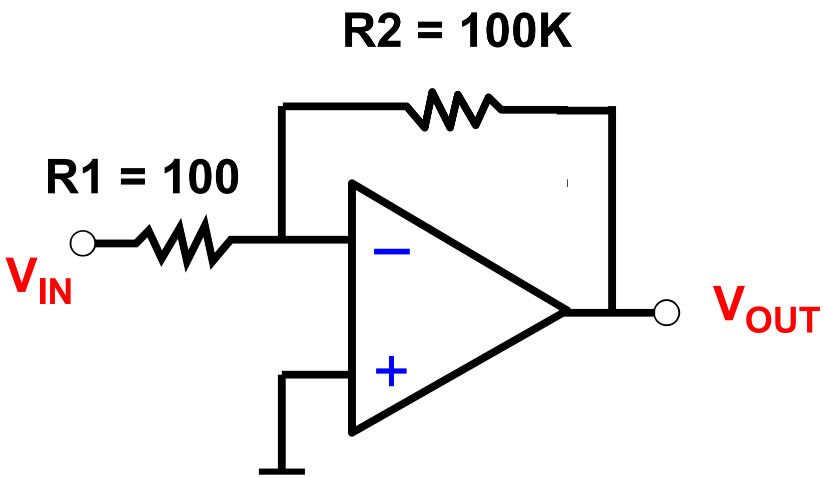


1st-pole: 1 kHz **2nd-pole: 1 kHz**

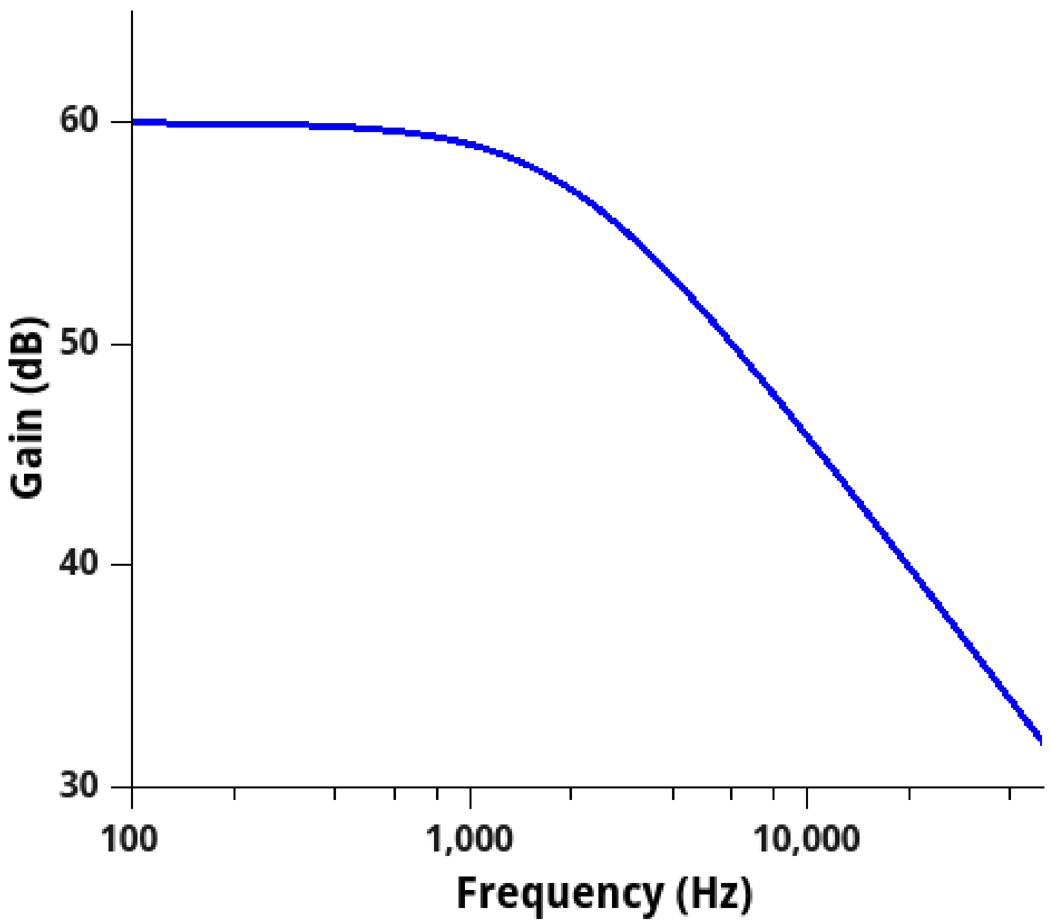




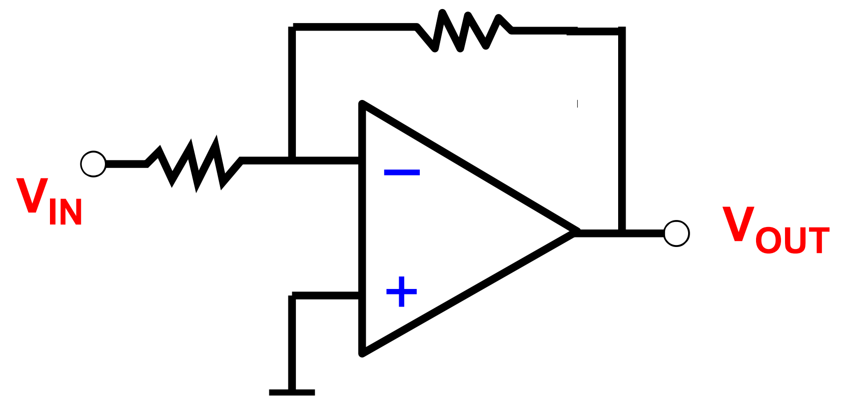
NON-IDEAL BEHAVIOR: GAIN-BANDWIDTH PRODUCT

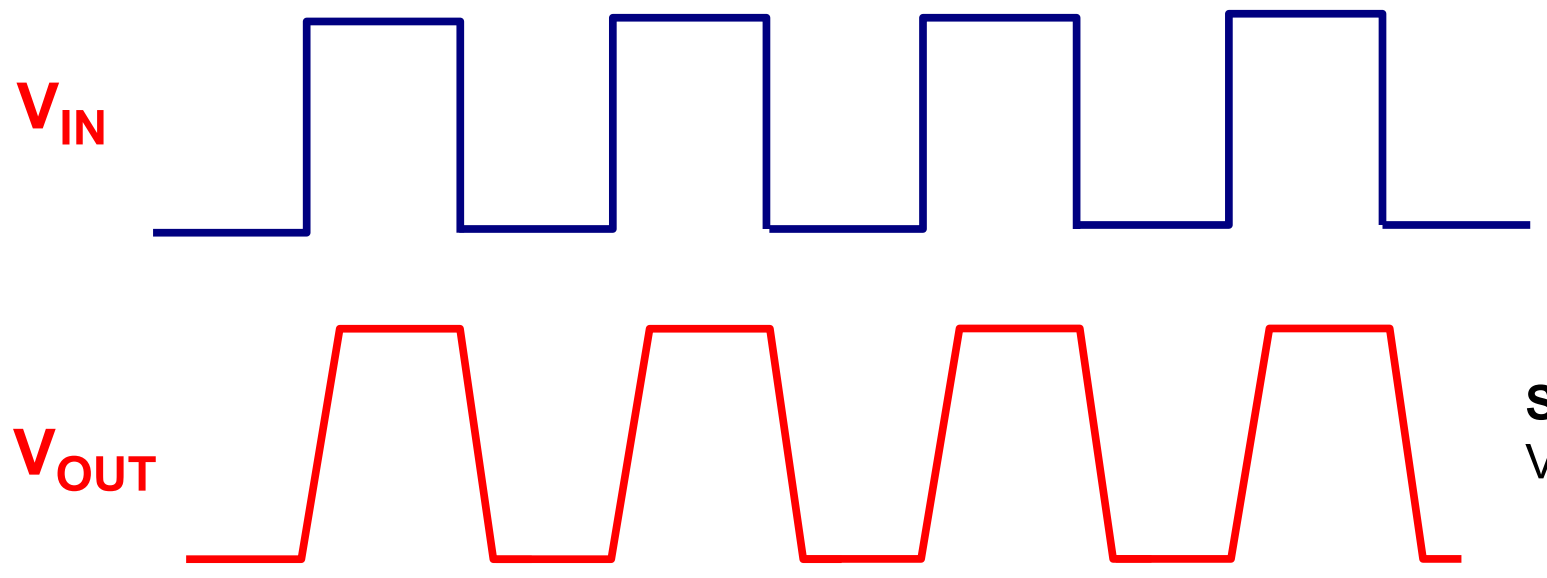


$$\text{GAIN} = -\frac{R2}{R1} = 60\text{ dB}$$



NON-IDEAL BEHAVIOR: SLEWING





SLOPE:
V/μs