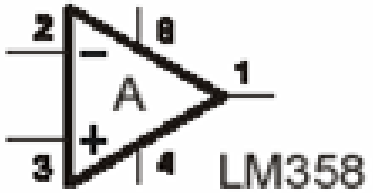
Lecture 18

Op-Amps

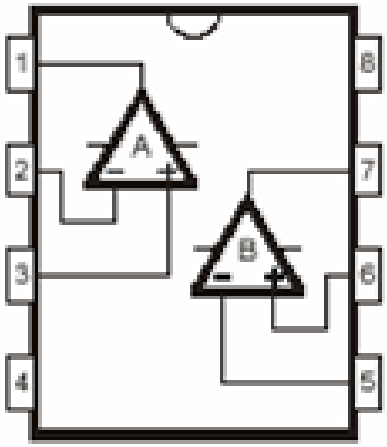
Op-Amps

- Op-Amps is a low-cost and versatile IC consisting of many internal transistors, resistors, and capacitors.
- Amplifiers
- Integrators
- Summers
- Differentiators
- Comparators
- Active filters

Require external power



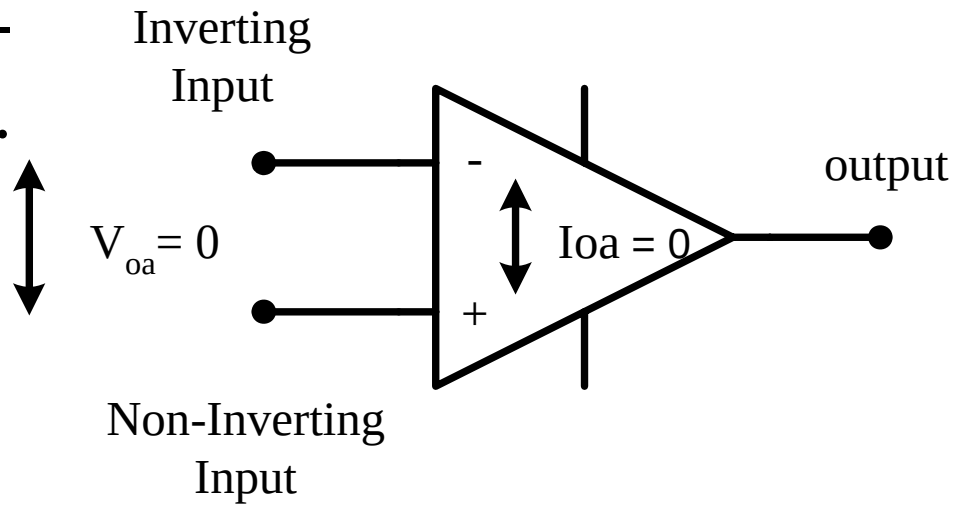
LM358



Dual Op-Amps (**LM358**)

Two Rules for Op-Amp Circuits

- There is no current flow through the op-amps input terminal. ($I_{oa} = 0$)
- The voltage drop across the input terminals is zero. ($V_{oa} = 0$)



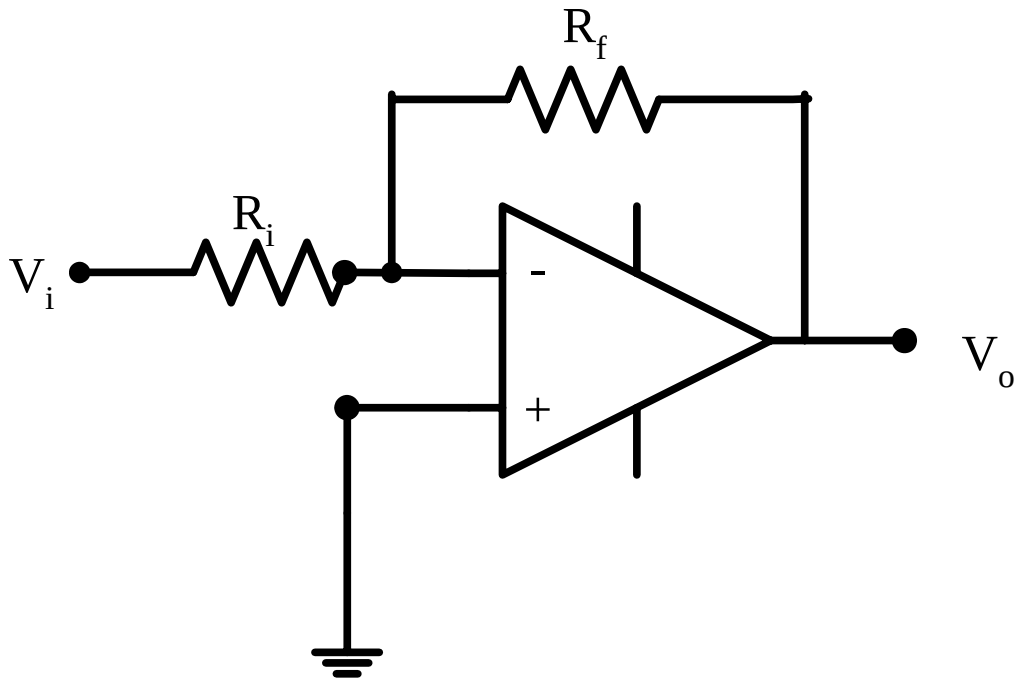
Amplifiers

- Inverting Amplifier
- Non-Inverting Amplifier
- Summing Amplifier
- Integrator Amplifier
- Differentiator Amplifier

Inverting Amplifier

- Gain = $\frac{V_o}{V_i}$

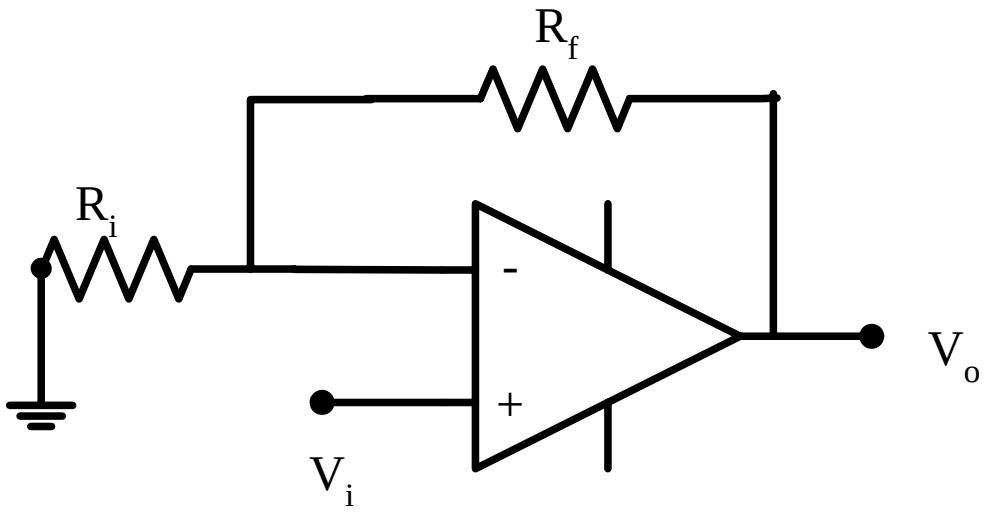
$= -\frac{R_f}{R_i}$



Non-Inverting Amplifier

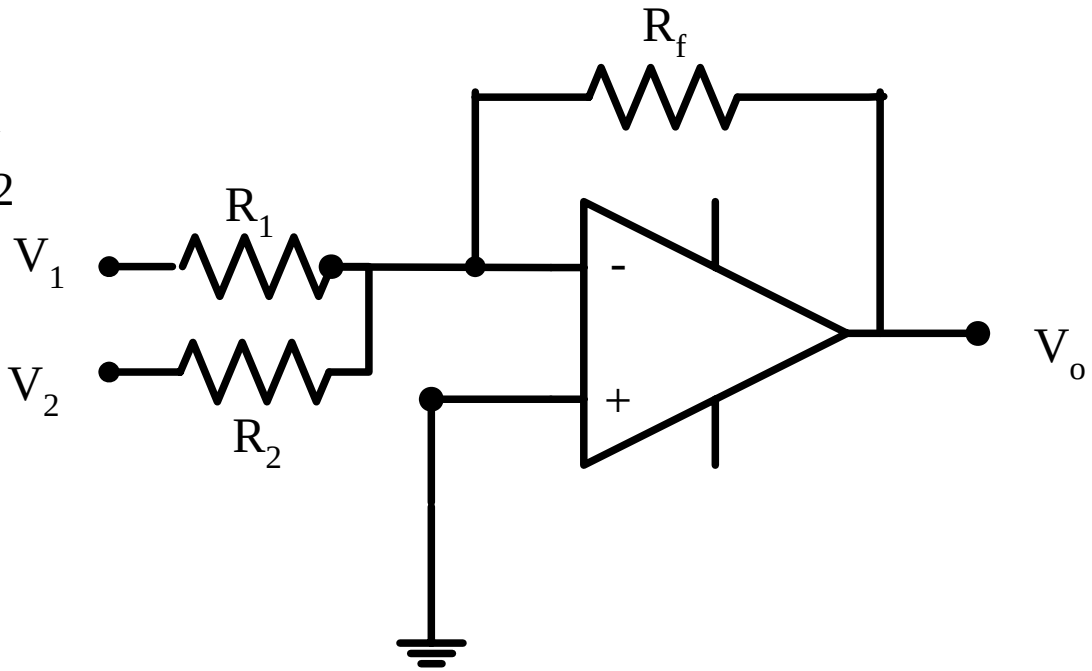
- Gain = $\frac{V_o}{V_i}$

$= 1 + \frac{R_f}{R_i}$



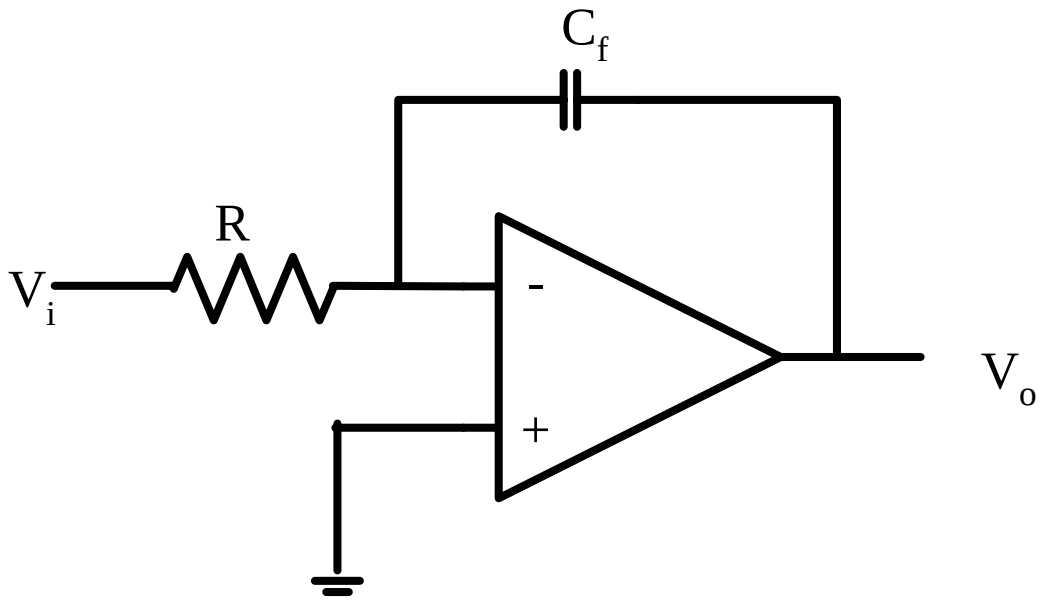
Summing Amplifier

$$V_o = -\frac{R_f}{R_1}V_1 - \frac{R_f}{R_2}V_2$$



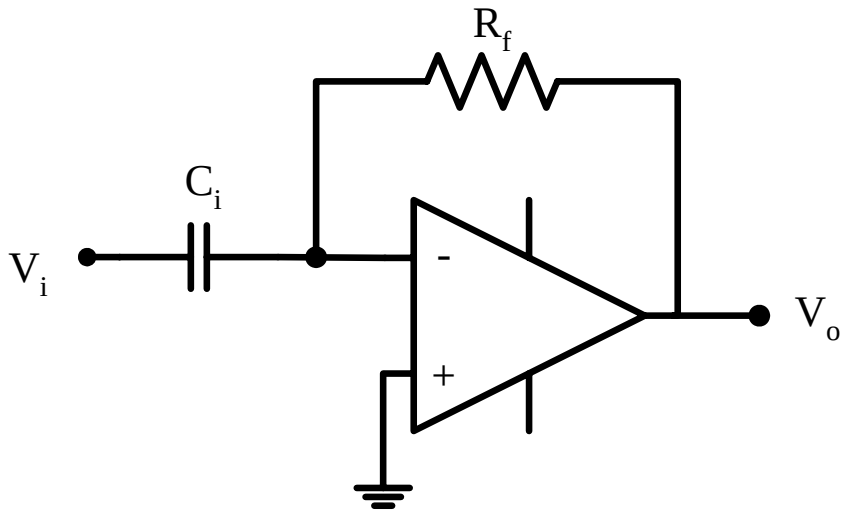
Integrator Amplifier

$$V_o = -\frac{1}{C_f R}\int_{t_0}^{t} V_i \, d\tau$$



Differentiator Amplifier

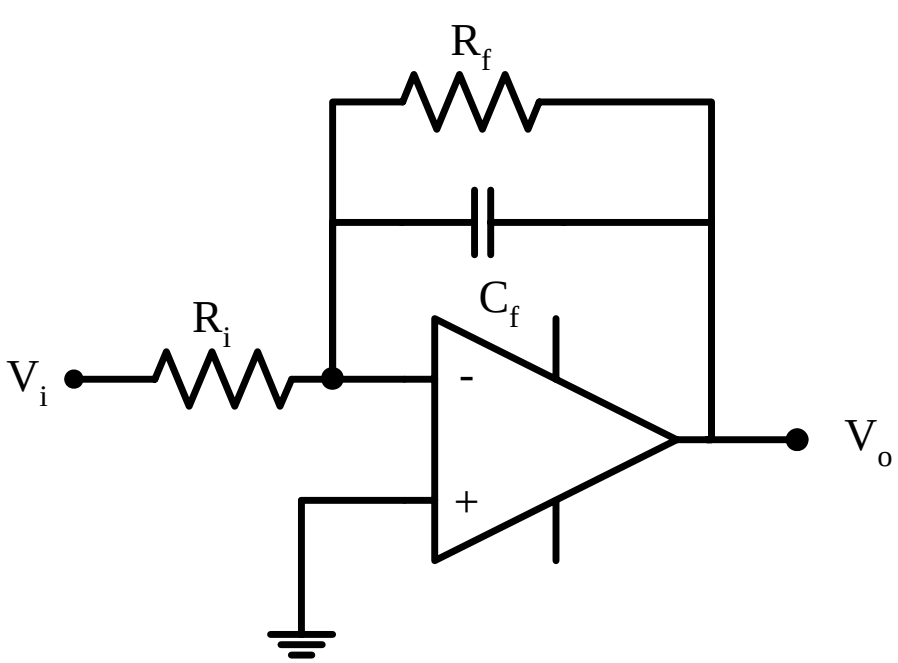
$$V_o = -C_i R_f \frac{dV_i}{dt}$$



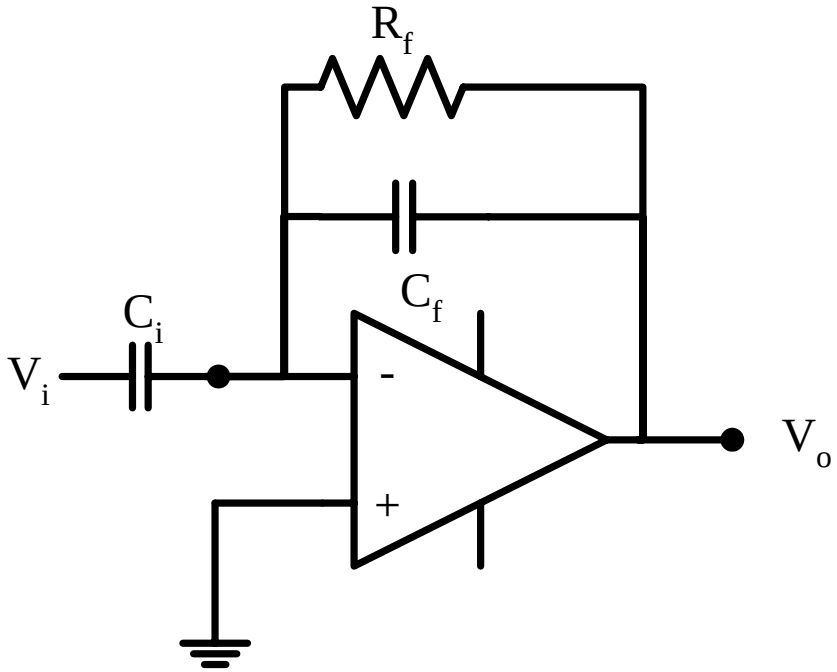
Active Filters

- First-Order Low-Pass Filter
- Second-Order Low-Pass Filter
- First-Order High-Pass Filter
- Second-Order High-Pass Filter
- Notch Filter
- Band-Pass Filter

Active First-Order Filter

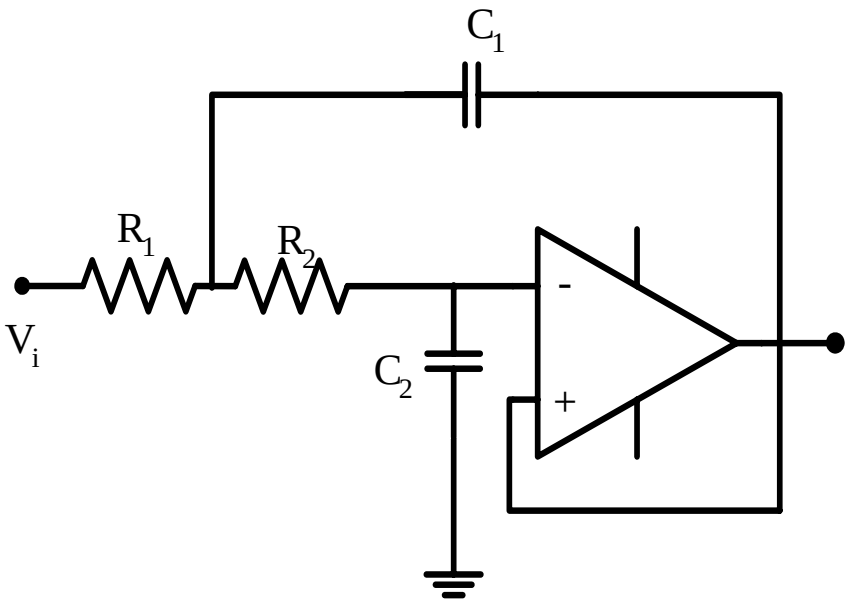


Low-Pass Filter

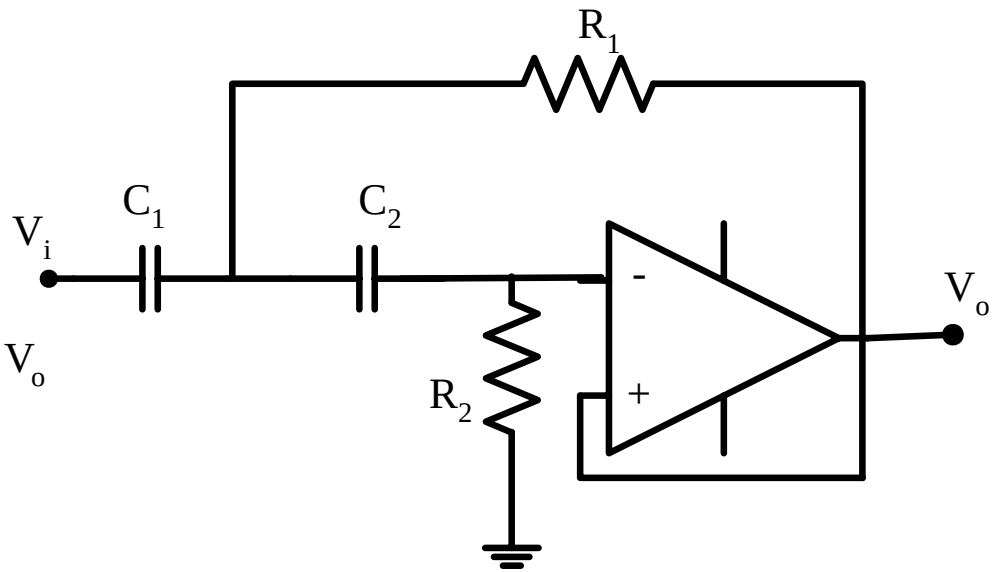


High-Pass Filter

Active Second-Order Filters



Low-Pass Filter



High-Pass Filter

Notch Filter

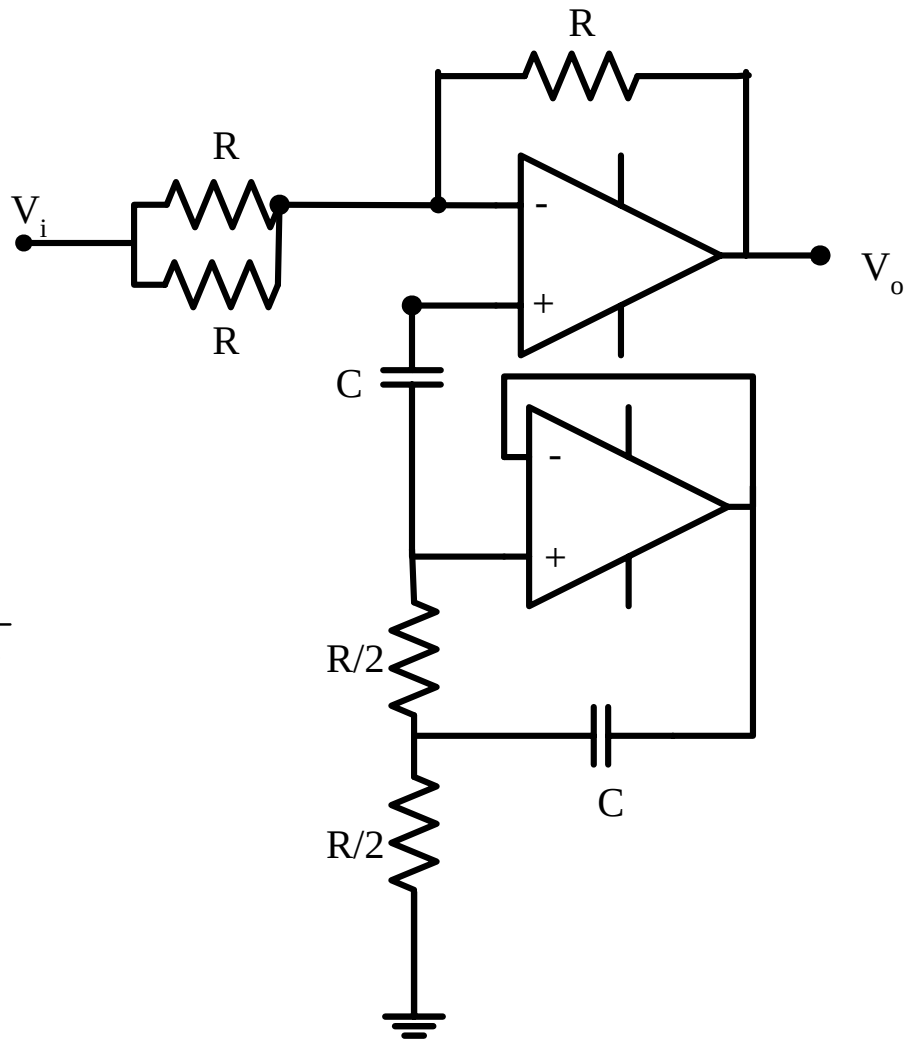
- Notch (or band-stop) filters are useful in measurement systems containing undesirable signal of fixed frequency. It can reduce the undesirable frequency to a tolerance level.

$$A_n(s) = \frac{V_o(s)}{V_i(s)} = \frac{s^2 + \omega_0^{\,2}}{s^2 + 2\omega_0 s + \omega_0^{\,2}}$$

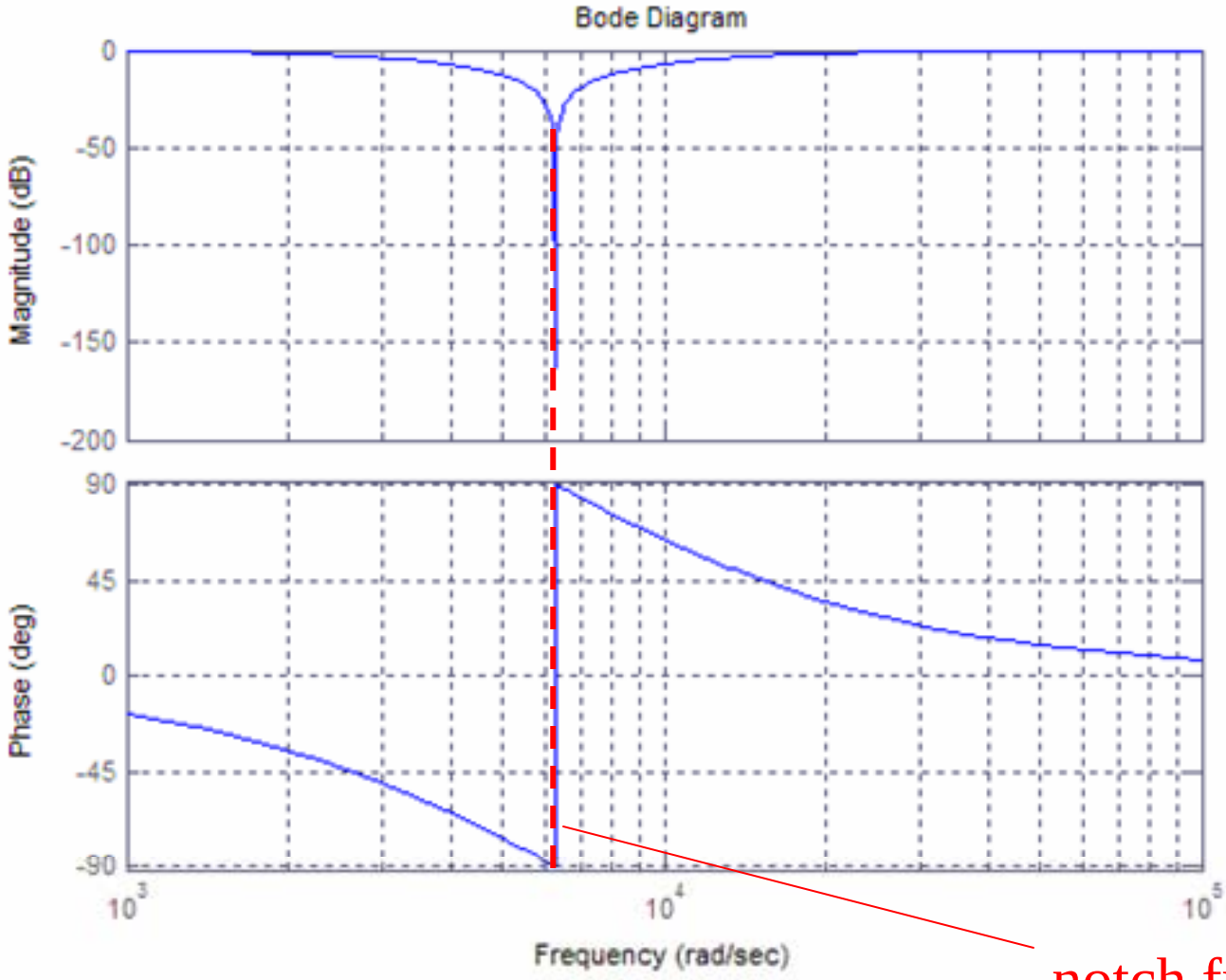
$$\omega_0 = \frac{1}{RC}$$

$A_n(s)$ is transfer function

ω_0 is notch frequency



Bode Plot of Active Notch Filter



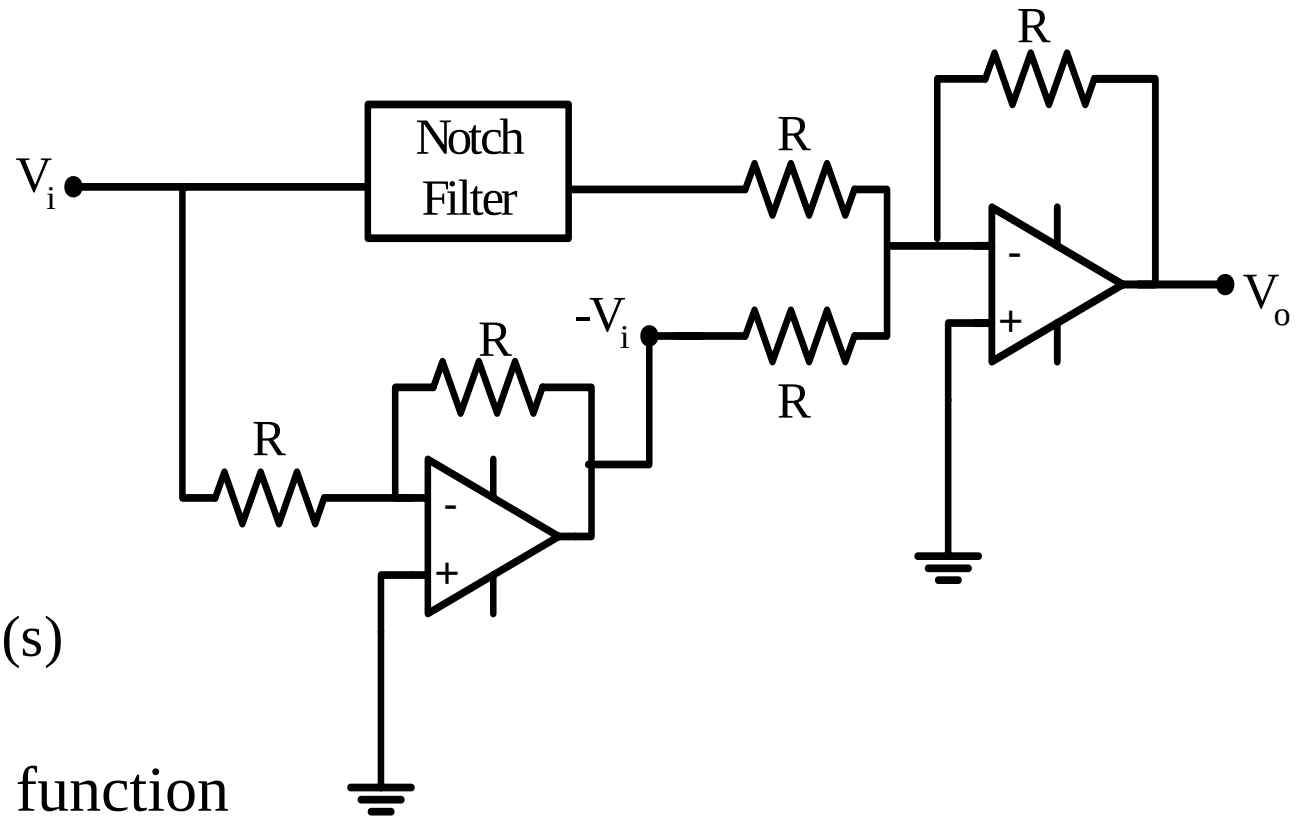
notch frequency

Band-Pass Filter

- Band-Pass filters are used when certain frequencies of a signal need to be emphasized while the rest be attenuated.

$$G(s) = \frac{V_o(s)}{V_i(s)} = 1 - A_n(s)$$

$A_n(s)$ is the transfer function of notch filter



Band-Pass Filter

Bode Plot of Band-Pass Filter