Unit-2
Lecture-6

First and second order LP, HP, BP BS and All pass active filters, KHN,
Tow-Thomas and State Variable Biquad filters

ACTIVE LOW-PASS FILTERS

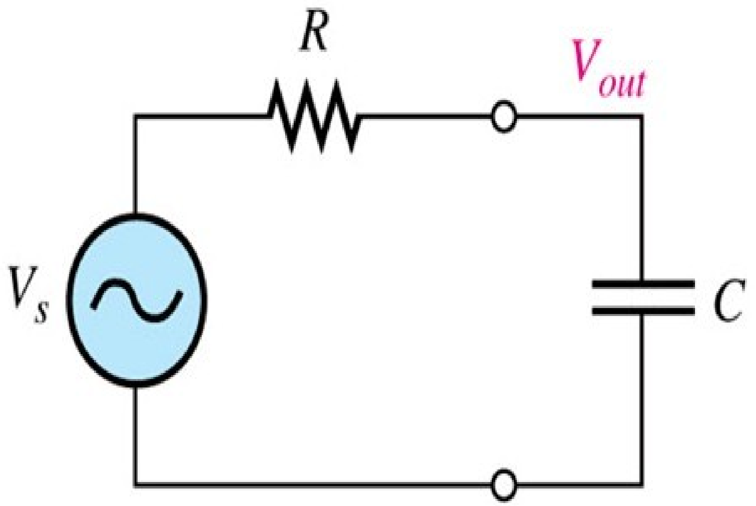
Advantages of active filters over passive filters (R, L, and C elements only):

1. By containing the op-amp, active filters can be designed to provide required gain, and hence **no signal attenuation** as the signal passes through the filter.

2. **No loading problem**, due to the high input impedance of the op-amp prevents excessive loading of the driving source, and the low output impedance of the op-amp prevents the filter from being affected by the load that it is driving.

3. **Easy to adjust over a wide frequency range** without altering the desired response.

- Figure below shows the basic Low-Pass filter circuit



(b) Basic low-pass circuit

At critical frequency,

Resistance = Capacitance

$$R = X_c$$

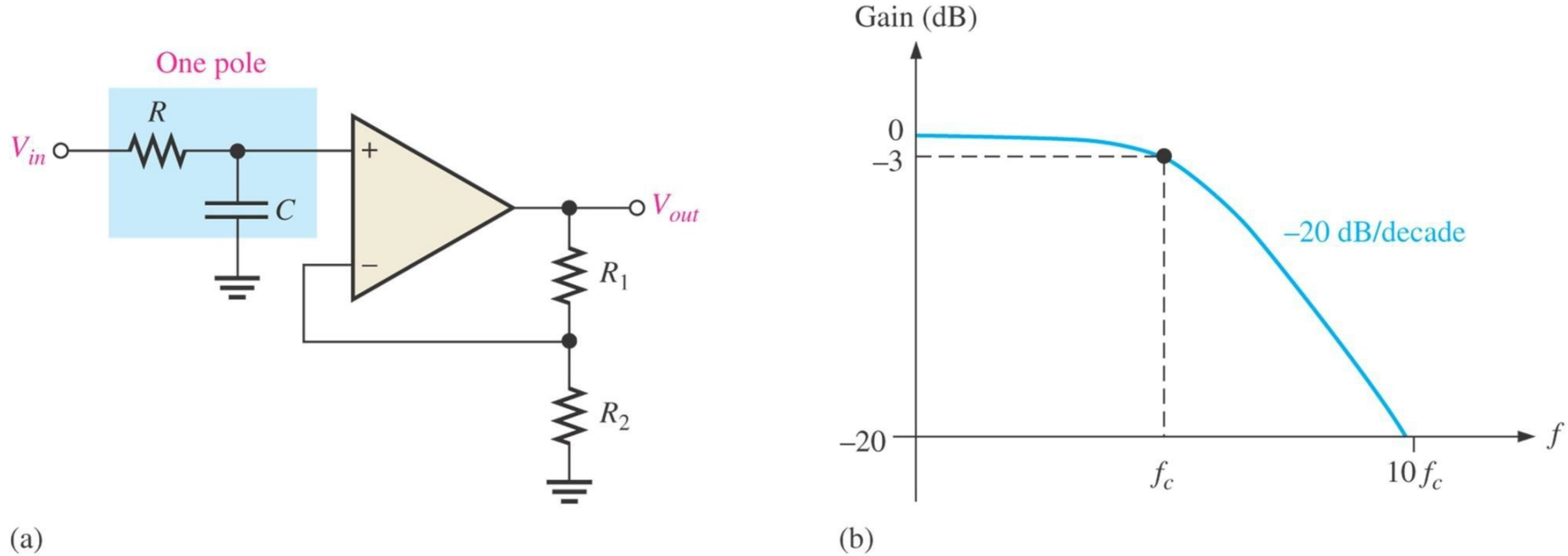
$$R = \frac{1}{\omega_c C}$$

$$R = \frac{1}{2\pi f_c C}$$

So, critical frequency ;

$$f_c = \frac{1}{2\pi RC}$$

Single-Pole Filter



Single-pole active low-pass filter and response curve.

➢ This filter provides a roll-off rate of -20 dB/decade above the critical frequency.

- The op-amp in single-pole filter is connected as a noninverting amplifier with the closed-loop voltage gain in the passband is set by the values of R_1 and R_2 :

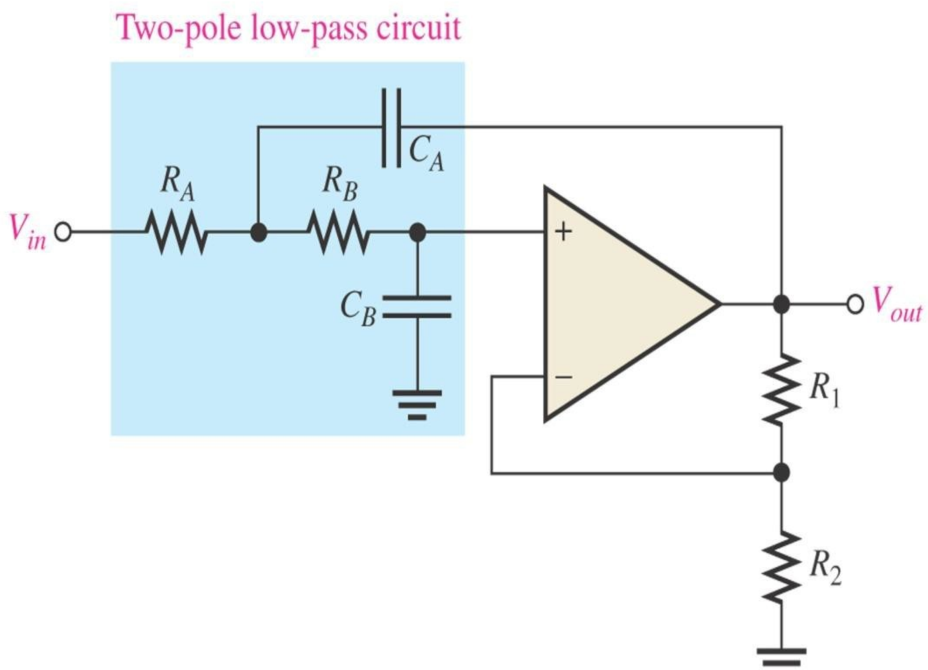
$$A_{cl(NI)} = \frac{R_1}{R_2} + 1$$

- The critical frequency of the single-pole filter is :

$$f_c = \frac{1}{2\pi RC}$$

Sallen-Key Low-Pass Filter

- **Sallen-Key** is one of the most common configurations for a **second order** (two-pole) filter.



Basic Sallen-Key low-pass filter.

- There are two low-pass RC circuits that provide a **roll-off of -40 dB/decade above f_c** (assuming a Butterworth characteristics).
- One RC circuit consists of R_A and C_A, and the second circuit consists of R_B and C_B.

- The critical frequency for the Sallen-Key filter is :

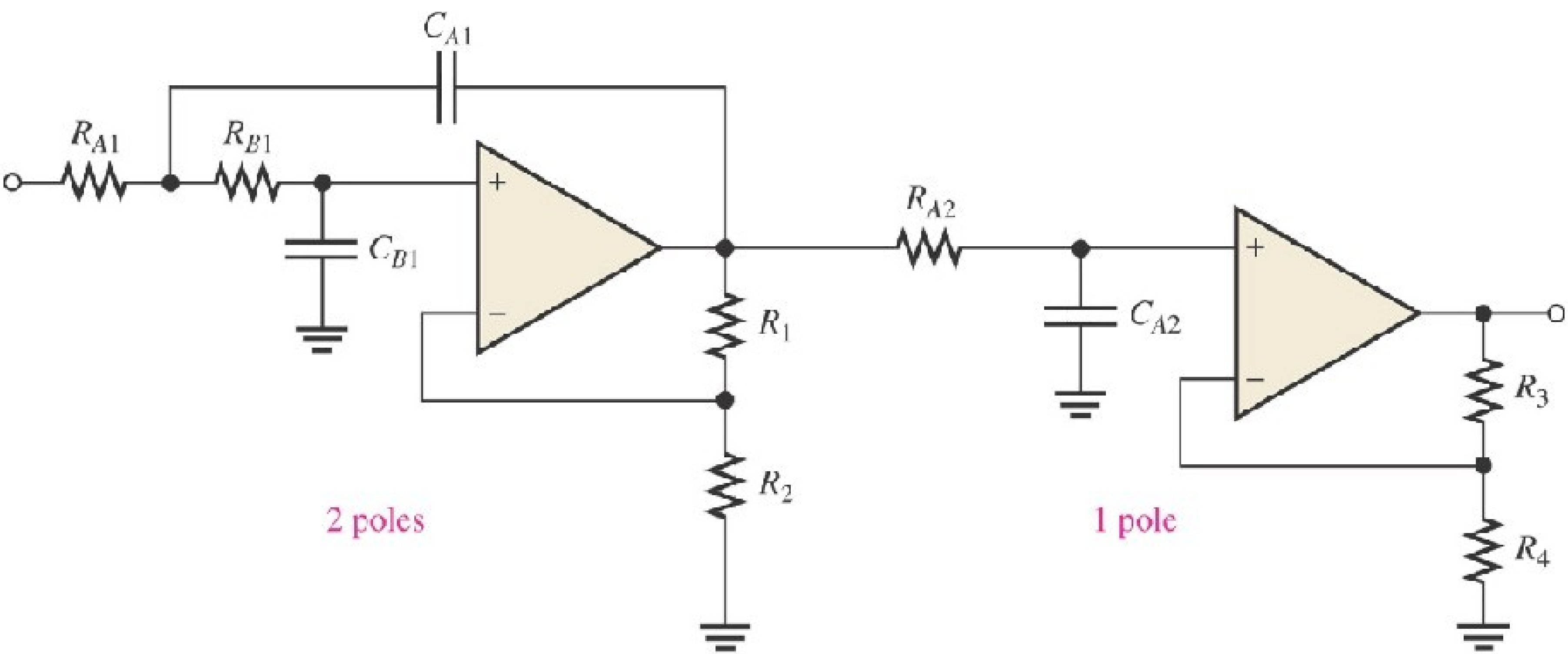
$$f_c = \frac{1}{2\pi\sqrt{R_A R_B C_A C_B}}$$

- For $R_A = R_B = R$ and $C_A = C_B = C$, thus the critical frequency :

$$f_c = \frac{1}{2\pi RC}$$

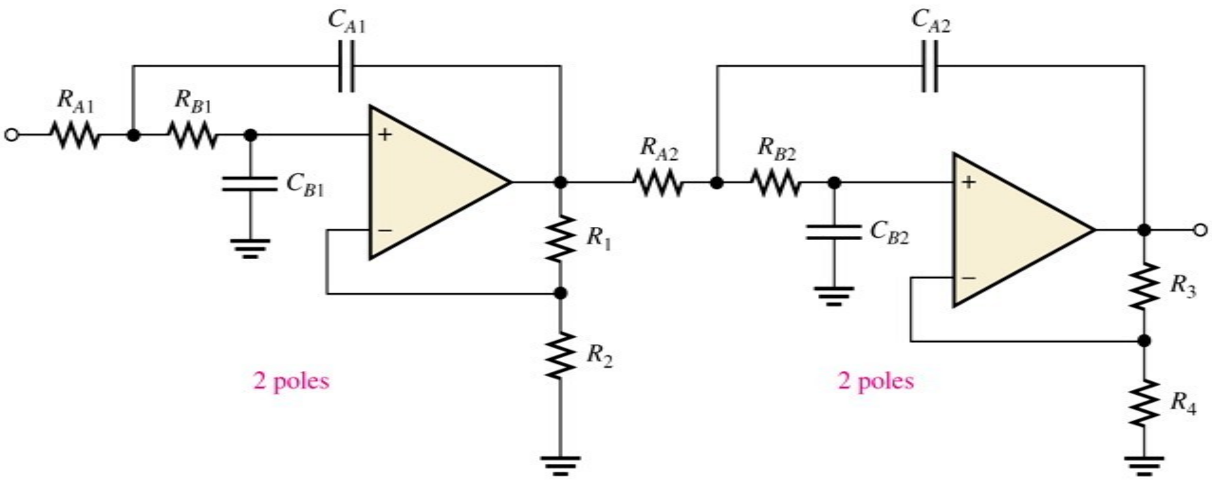
Cascading Low-Pass Filter

- **A three-pole filter** is required to provide a roll-off rate of **-60 dB/decade**. This is done by cascading a **two-pole Sallen-Key low-pass filter** and a **single-pole low-pass filter**.



Cascaded low-pass filter: third-order configuration.

- **A four-pole filter** is required to provide a roll-off rate of **-80 dB/decade**. This is done by cascading a **two-pole Sallen-Key low-pass filter** and a **two-pole Sallen-Key low-pass filter.**

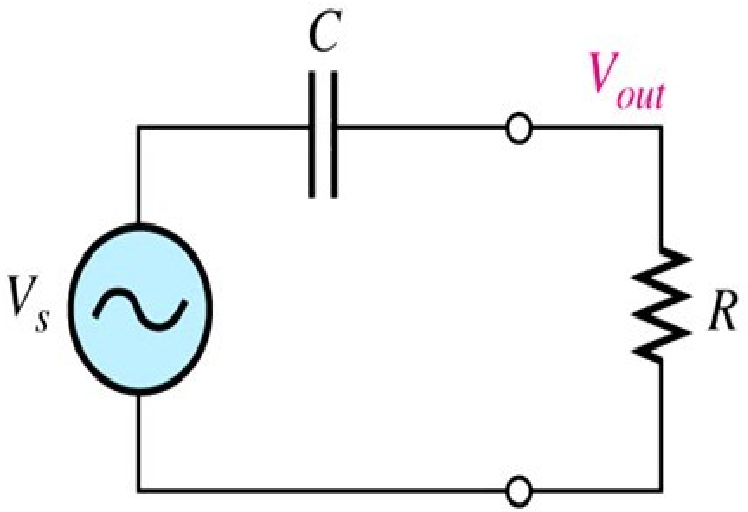


(b) Fourth-order configuration

Cascaded low-pass filter: fourth-order configuration.

ACTIVE HIGH-PASS FILTERS

- Figure below shows the basic High-Pass filter circuit :



(b) Basic high-pass circuit

At critical frequency,

Resistance = Capacitance

$$R = X_c$$

$$R = \frac{1}{\omega_c C}$$

$$R = \frac{1}{2\pi f_c C}$$

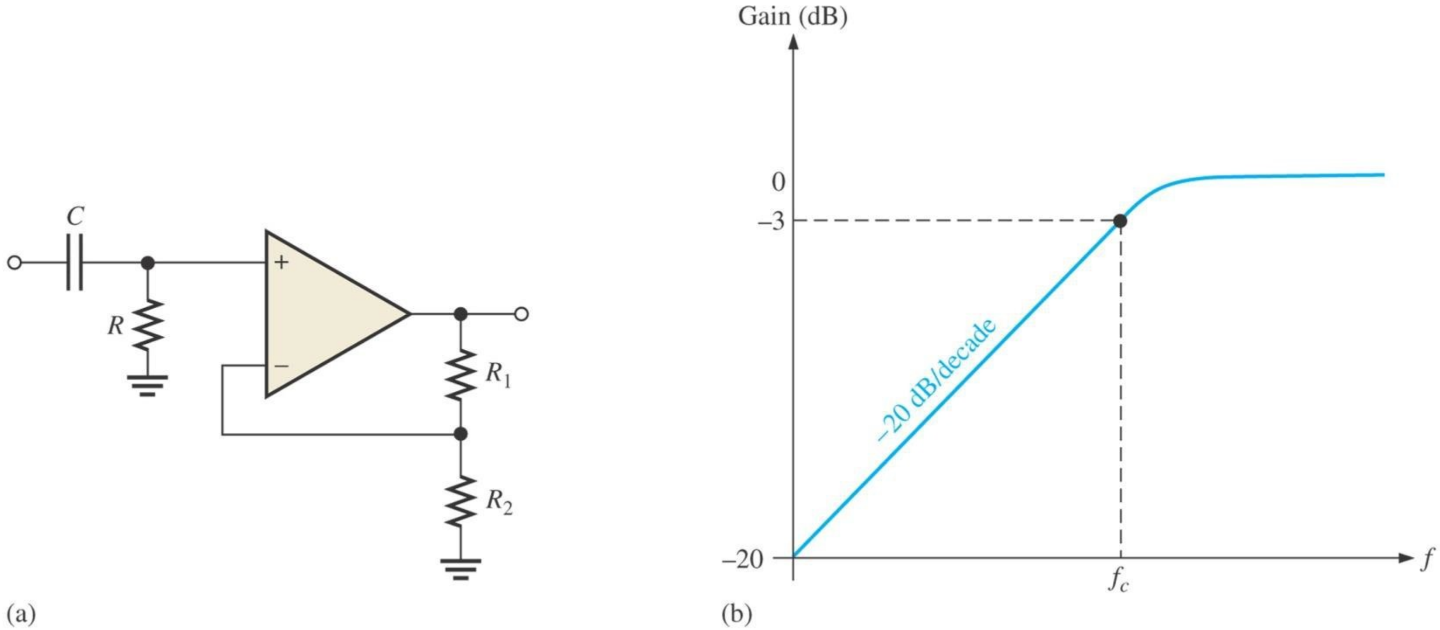
So, critical frequency ;

$$f_c = \frac{1}{2\pi RC}$$

Single-Pole Filter

- In high-pass filters, the roles of the **capacitor** and **resistor** are **reversed** in the RC circuits as shown from Figure (a). The negative feedback circuit is the same as for the low-pass filters.

- Figure (b) shows a high-pass active filter with a -20dB/decade roll-off



Single-pole active high-pass filter and response curve.

- The op-amp in single-pole filter is connected as a noninverting amplifier with the closed-loop voltage gain in the passband is set by the values of R_1 and R_2 :

$$A_{cl(NI)} = \frac{R_1}{R_2} + 1$$

- The critical frequency of the single-pole filter is :

$$f_c = \frac{1}{2\pi RC}$$

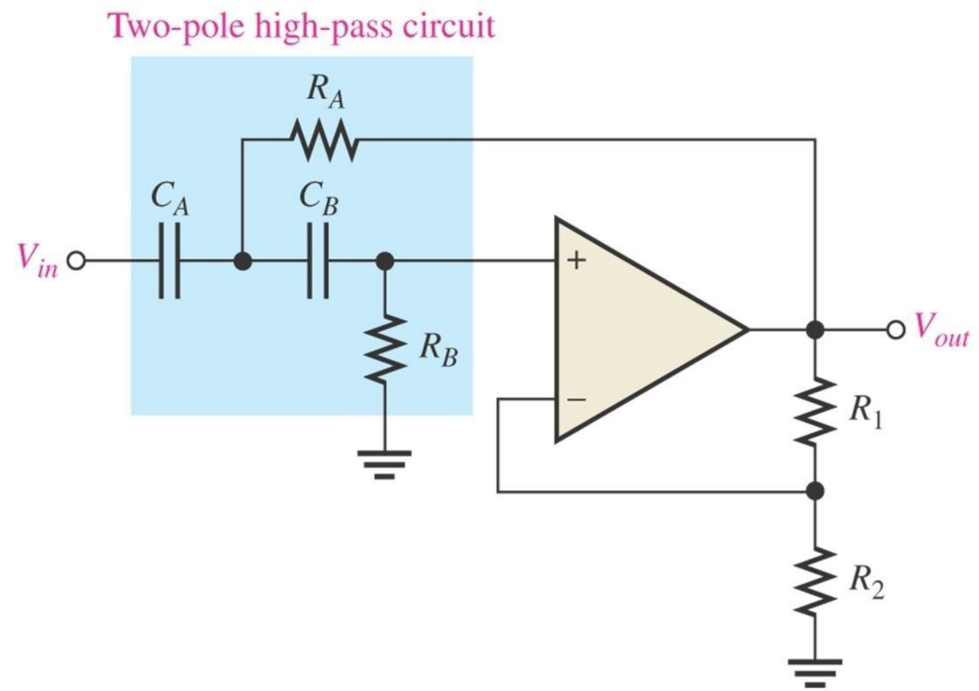
Sallen-Key High-Pass Filter

- Components R_A, C_A, R_B, and C_B form the **second order** (two-pole) frequency-selective circuit.

- The position of the resistors and capacitors in the frequency-selective circuit are **opposite** in low pass configuration.

- There are two high-pass RC circuits that provide a **roll-off of -40 dB/decade above fc**

- The **response characteristics** can be optimized by proper selection of the **feedback resistors**, R_1 and R_2.



Basic Sallen-Key high-pass filter.

- The critical frequency for the Sallen-Key filter is :

$$f_c = \frac{1}{2\pi\sqrt{R_A R_B C_A C_B}}$$

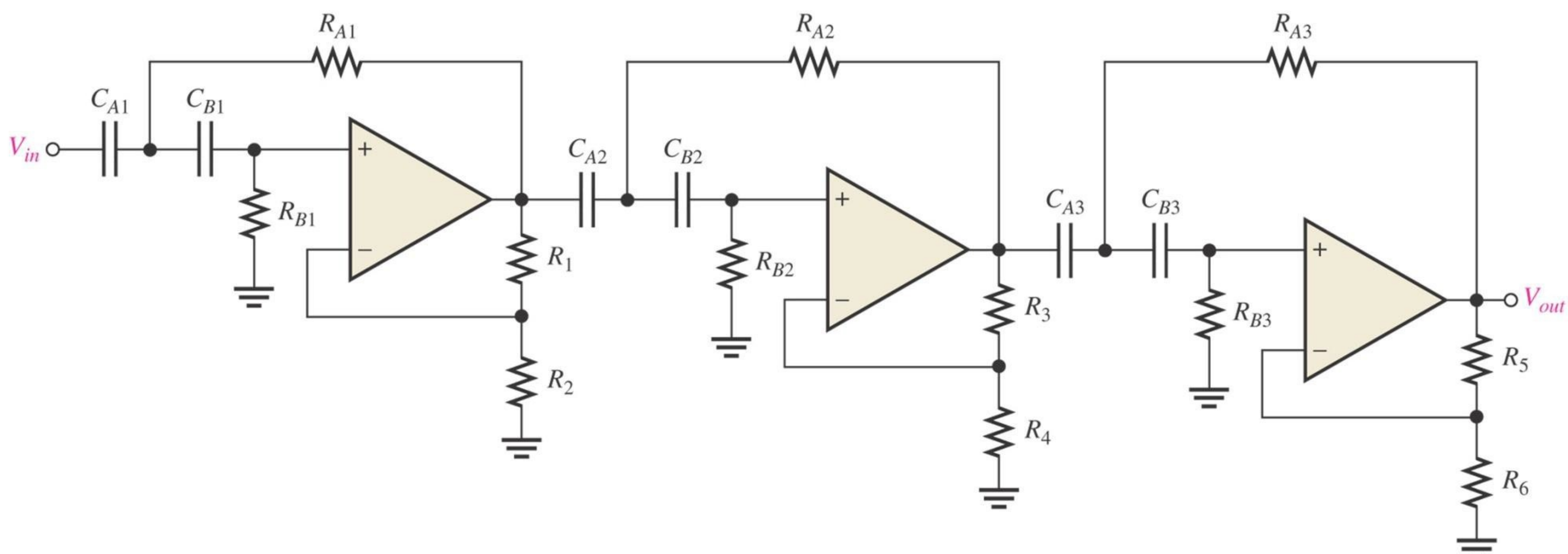
- For $R_A = R_B = R$ and $C_A = C_B = C$, thus the critical frequency :

$$f_c = \frac{1}{2\pi RC}$$

Cascading High-Pass Filter

➢ As with the low-pass filter, first- and second-order high-pass filters can be cascaded to provide three or more poles and thereby create faster roll-off rates.

➢A **six-pole high-pass filter** consisting of **three Sallen-Key two-pole** stages with the roll-off rate of **-120 dB/decade**



Sixth-order high-pass filter