Chapter 6:
System Realization Using Operational Amplifiers

1. ***Basic Circuits of Operational Amplifiers*** ◀
2. *First order systems*
3. *Second order systems*

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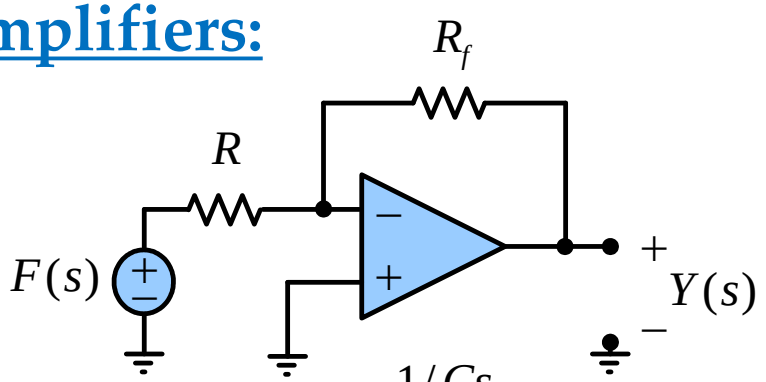
Basic Circuits of Operational Amplifiers:

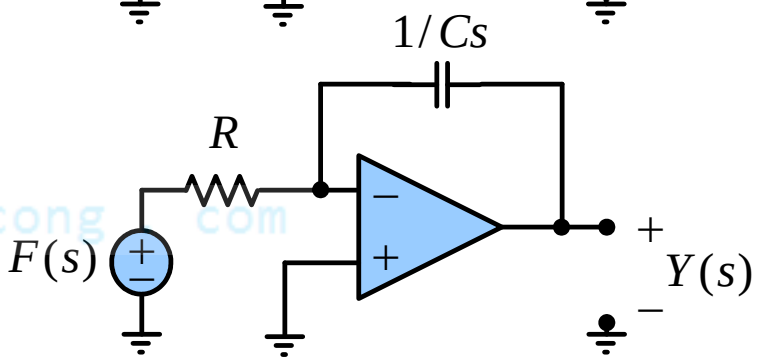
- Inverting amplifier:

$$H(s) = -\frac{R_f}{R}$$



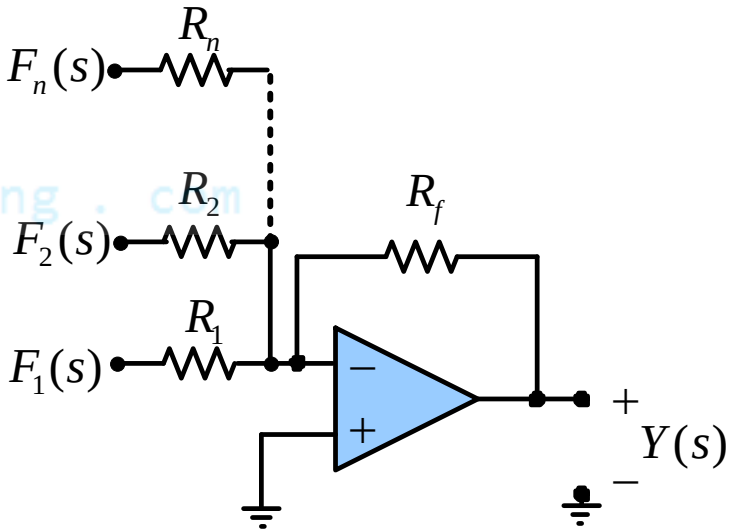
- Inverting integrator:

$$H(s) = -\frac{1}{RCs}$$



- Summing amplifier:

$$Y(s) = -R_f\left[\frac{F_1(s)}{R_1} + \frac{F_2(s)}{R_2} + \ldots \frac{F_n(s)}{R_n}\right]$$



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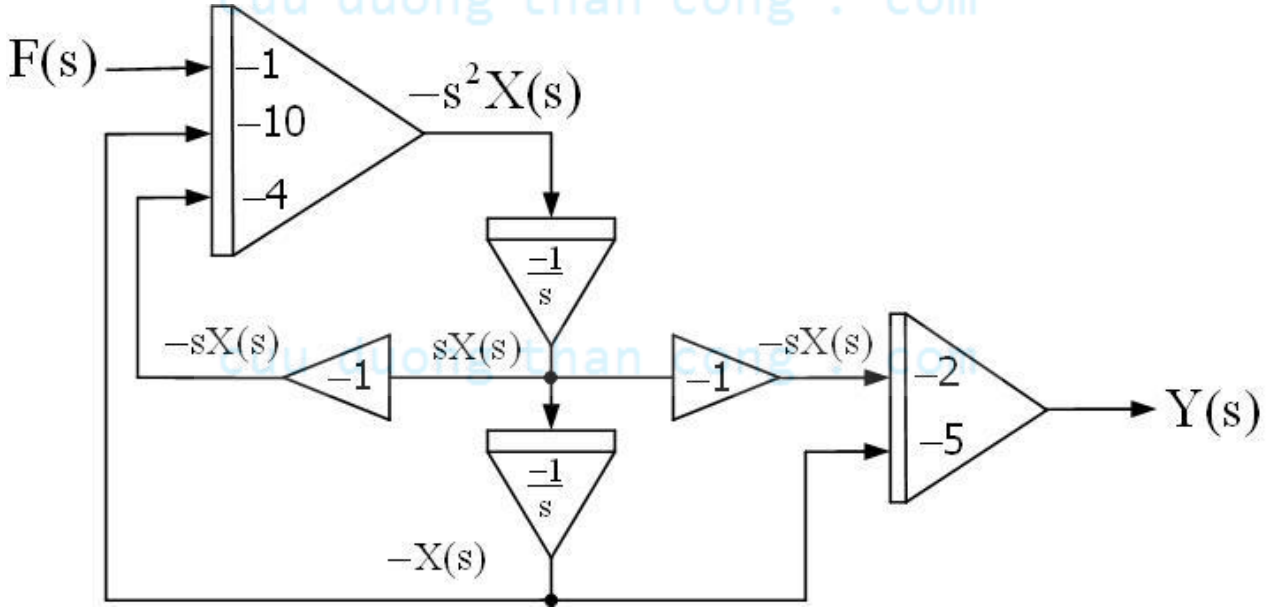
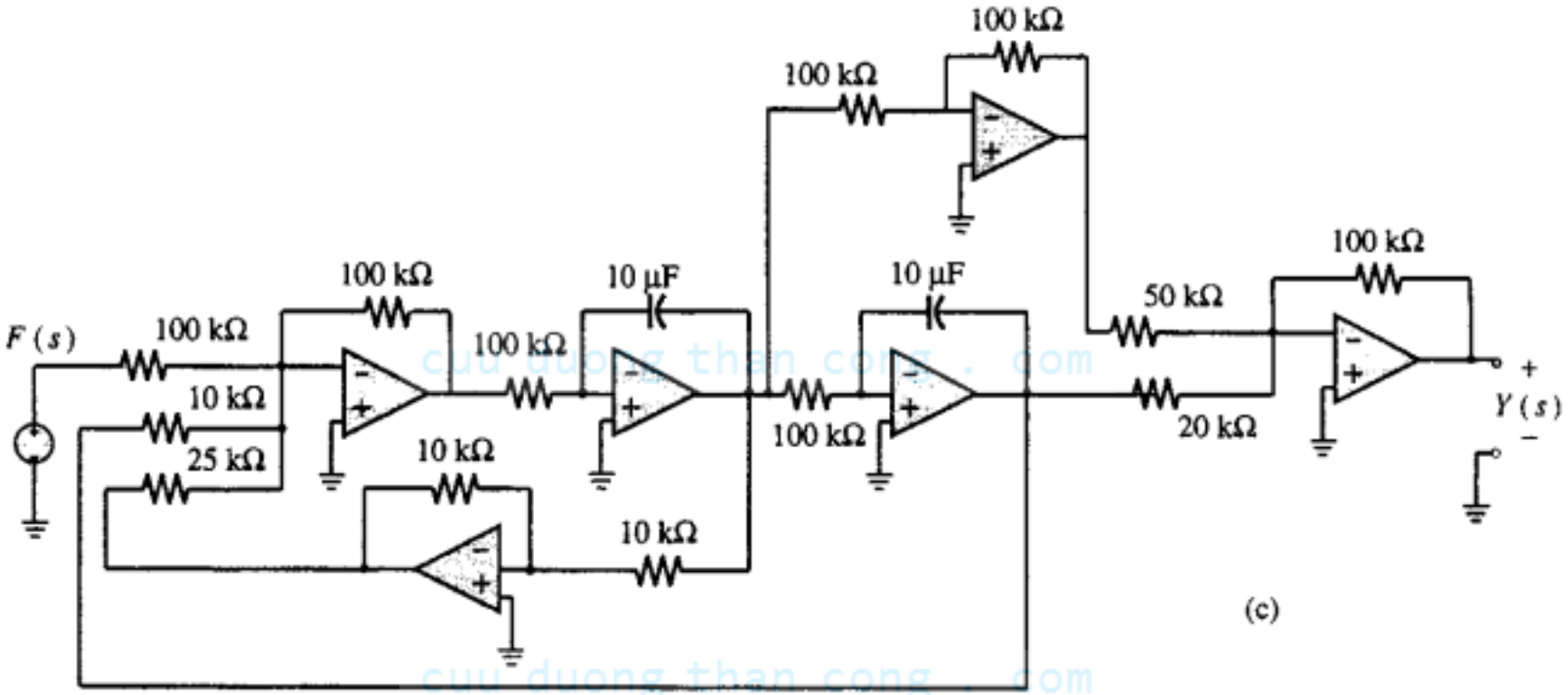
Basic Circuits of Operational Amplifiers:

- *Example 6.01:* Using op-amp circuits, realize the canonical form of the transfer function:

$$H(s) = \frac{2s+5}{s^2+4s+10}$$



Basic Circuits of Operational Amplifiers:



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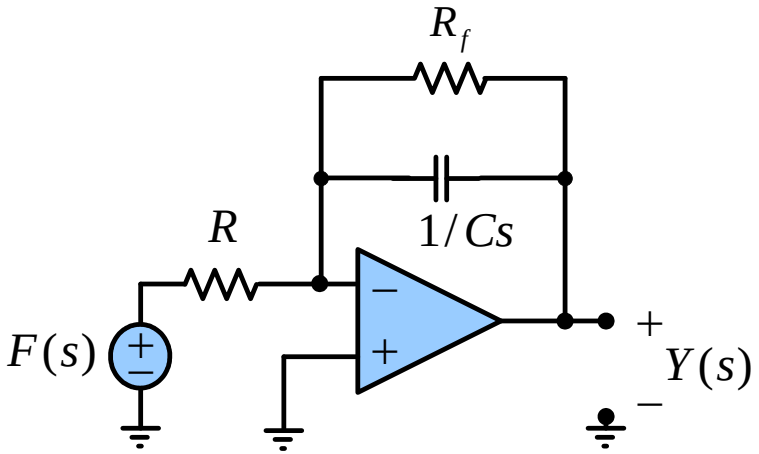
First order systems:

- Type 1

$$H(s) = \frac{ka}{s+a}$$

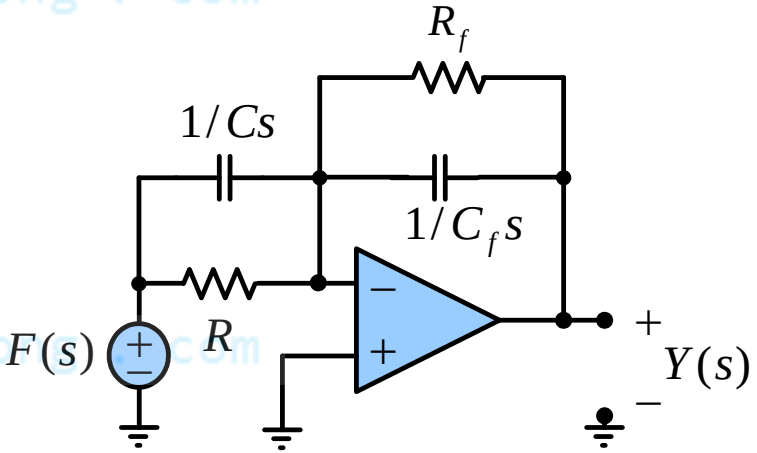
$$k = -\frac{R_f}{R};\quad a = \frac{1}{R_f C}$$



- Type 2

$$H(s) = \frac{k(s+a)}{s+b}$$

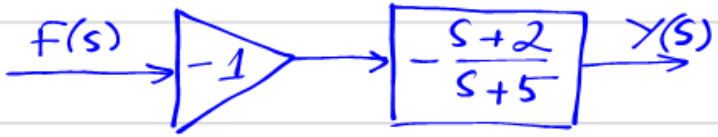
$$k = -\frac{C}{C_f};\ a = \frac{1}{R_f C_f};\ b = \frac{1}{RC}$$

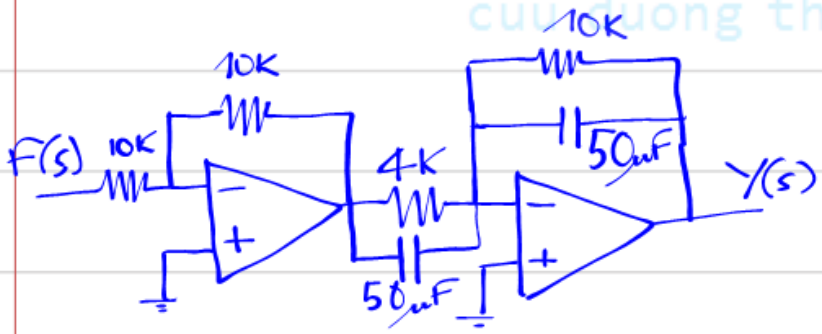


First order systems:

- *Example 6.02*

$$H(s) = \frac{s+2}{s+5}$$





Inverting amplifier:

$$H(s) = -1 = -\frac{R_f}{R}$$

$$\Rightarrow R_f = R = 10K$$

First order system

$$a = 2 = \frac{1}{R_f . C_f}$$

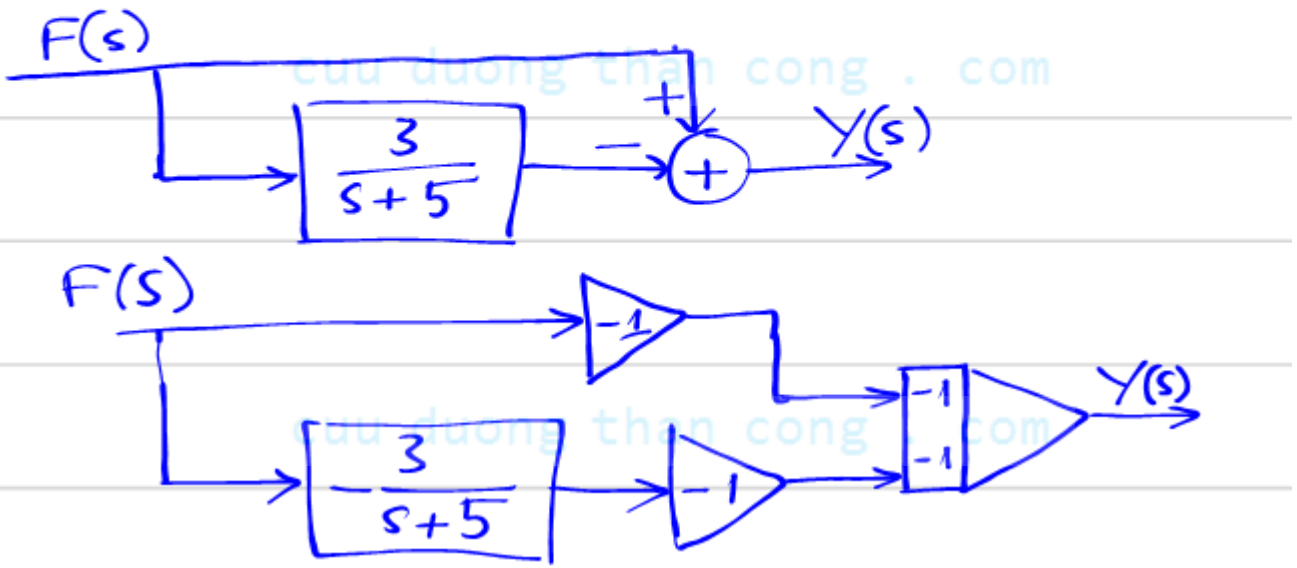
$$R_f = 10K \Rightarrow C_f = 50\mu F$$

$$k = -1 = -\frac{C}{C_f} \Rightarrow C = C_f = 50\mu F \; ; \; b = 5 = \frac{1}{RC} \Rightarrow R = 4K$$

First order systems:

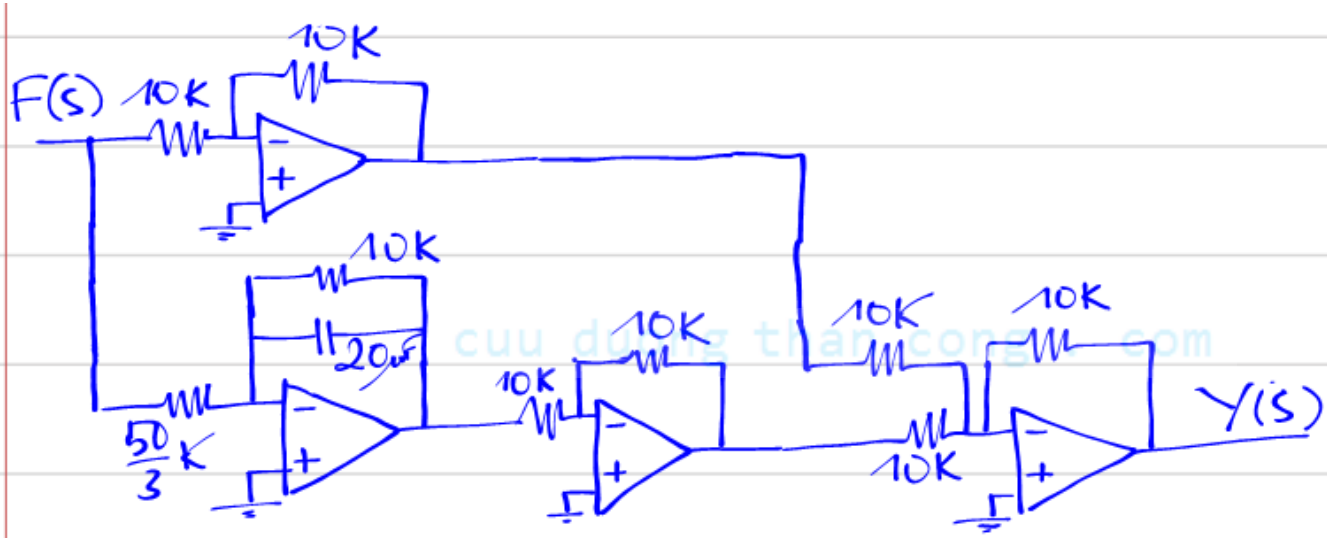
- *Example 6.02 (cont)*

$$H(s) = \frac{s+2}{s+5} = 1 - \frac{3}{s+5}$$



First order systems:

- *Example 6.02 (cont)*



First order system: $a = \frac{1}{R_f.C} = 5$, $R_f = 10K \Rightarrow C = 20uf$

$$K = -\frac{3}{5} = -\frac{R_f}{R} \Rightarrow R = \frac{50}{3}K$$

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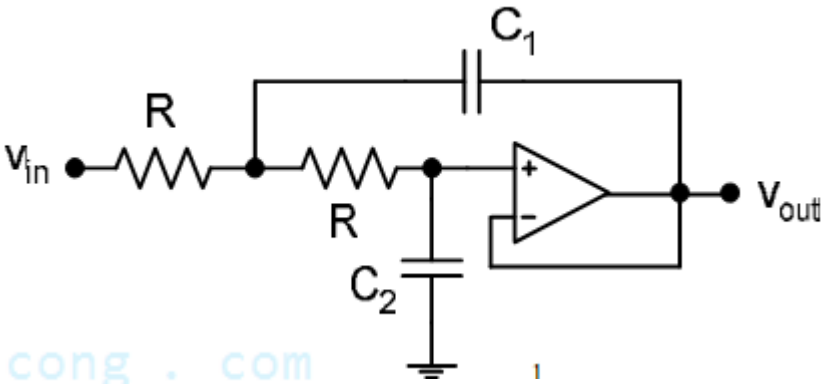
Second order systems:

Lowpass filter

- Type 1:

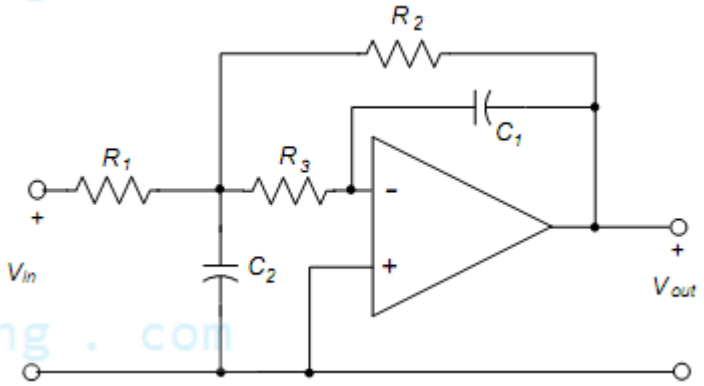
$$H(s) = \frac{\frac{1}{R^2 C_1 C_2}}{s^2 + \frac{2}{RC_1}s + \frac{1}{R^2 C_1 C_2}}$$



- Type 2:

$$H(s) = \frac{-ka_0}{s^2 + a_1 s + a_0}; a_0 = \frac{1}{R_2 R_3 C_1 C_2}$$

$$k = \frac{R_2}{R_1};\ a_1 = \frac{1}{C_2}\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$



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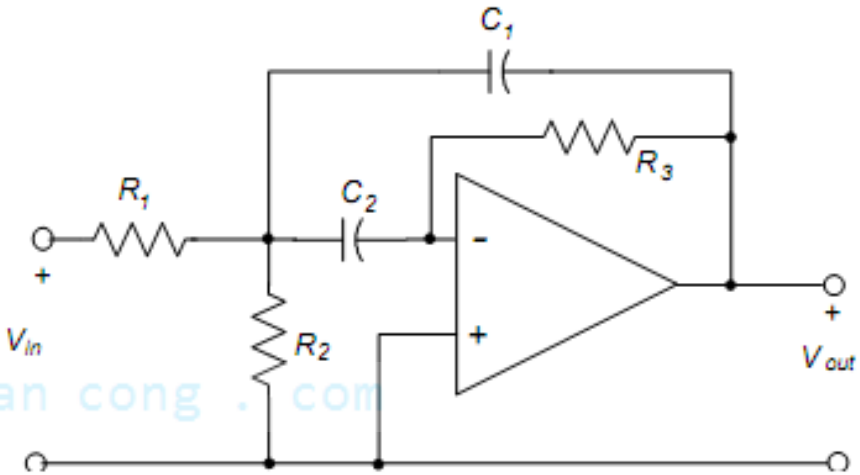
Second order systems:

Bandpass filter

$$H(s) = \frac{-ka_1 s}{s^2 + a_1 s + a_0}$$



$$a_0 = \frac{1}{R_3 C_1 C_2}\left(\frac{1}{R_1} + \frac{1}{R_2}\right); \quad a_1 = \frac{C_1 + C_2}{R_3 C_1 C_2}$$

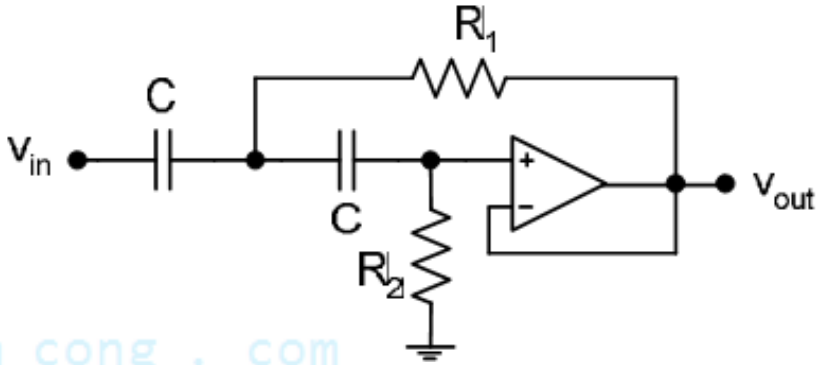
$$k = \frac{R_3 C_2}{R_1 (C_1 + C_2)};$$

Second order systems:

Highpass filter

- Type 1

$$H(s) = \frac{s^2}{s^2 + \frac{2}{R_2 C} s + \frac{1}{R_1 R_2 C^2}}$$



- Type 2

$$H(s) = \frac{-ks^2}{s^2 + a_1 s + a_0}; a_0 = \frac{1}{R_1 R_2 C_2 C_3}$$

$$k = \frac{C_1}{C_2}; \; a_1 = \frac{C_1 + C_2 + C_3}{R_2 C_2 C_3}$$