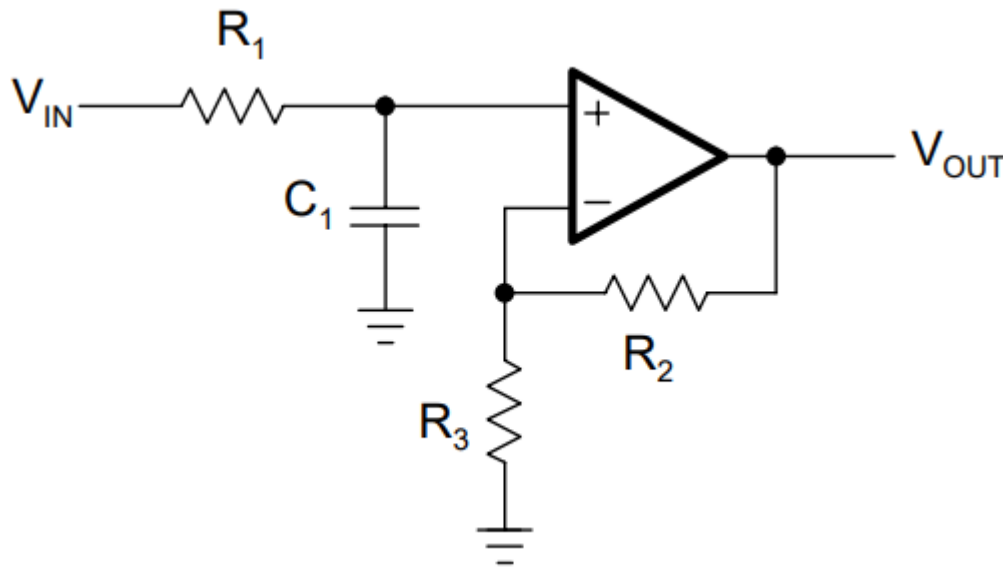


Активні фільтри

Ч.2. Класичні схеми АФ на ОП

ФНЧ першого порядку

Неінвертуюча схема



$$A(s) = \frac{1 + \frac{R_2}{R_3}}{1 + \omega_c R_1 C_1 s}$$

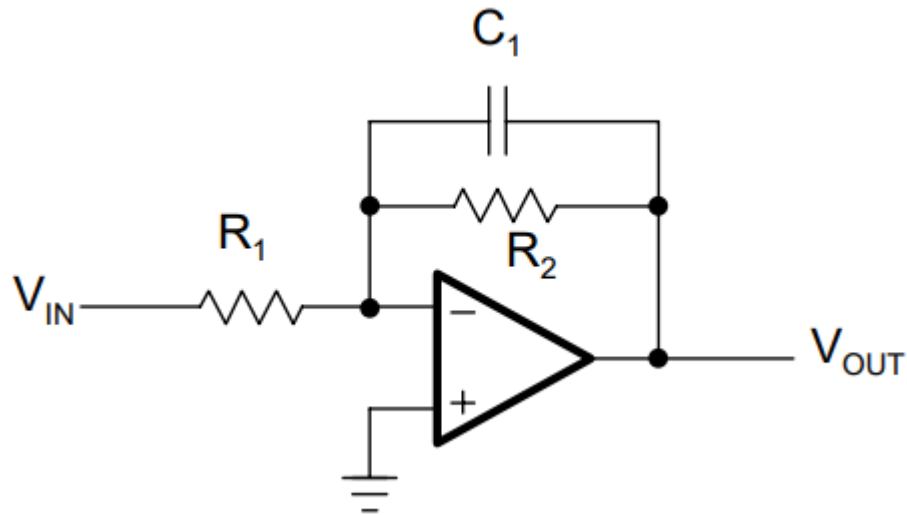
$$A_0 = 1 + \frac{R_2}{R_3}$$

$$a_1 = \omega_c R_1 C_1$$

$$R_1 = \frac{a_1}{2\pi f_c C_1} \quad R_2 = R_3(A_0 - 1)$$

ФНЧ першого порядку

Інвертуюча схема



$$A(s) = \frac{-\frac{R_2}{R_1}}{1 + \omega_c R_2 C_1 s}$$

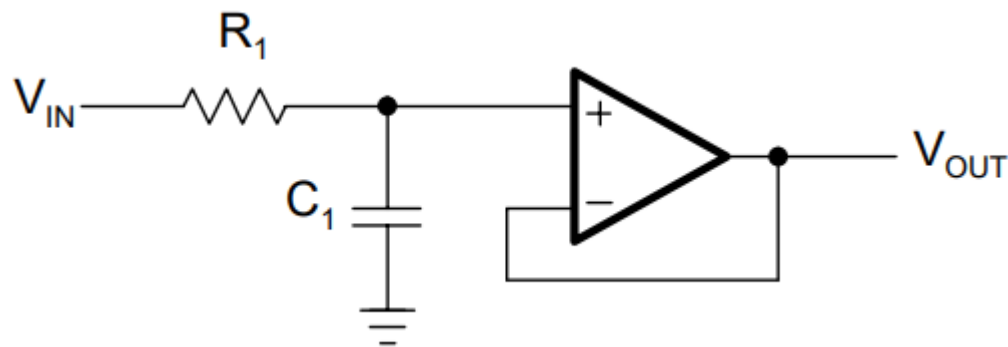
$$A_0 = -\frac{R_2}{R_1}$$

$$a_1 = \omega_c R_2 C_1$$

$$R_2 = \frac{a_1}{2\pi f_c C_1} \quad R_1 = -\frac{R_2}{A_0}$$

Приклад

Неінвертуюча схема з коефіцієнтом передачі 1



For a first-order unity-gain low-pass filter with $f_c = 1$ kHz and $C_1 = 47$ nF, R_1 calculates to:

$$R_1 = \frac{a_1}{2\pi f_c C_1} = \frac{1}{2\pi \cdot 10^3 \text{ Hz} \cdot 47 \cdot 10^{-9} \text{ F}} = 3.38 \text{ k}\Omega$$

However, to design the first stage of a third-order unity-gain Bessel low-pass filter, assuming the same values for f_c and C_1 , requires a different value for R_1 . In this case, obtain a_1 for a third-order Bessel filter from Table 16–4 in Section 16.9 (Bessel coefficients) to calculate R_1 :

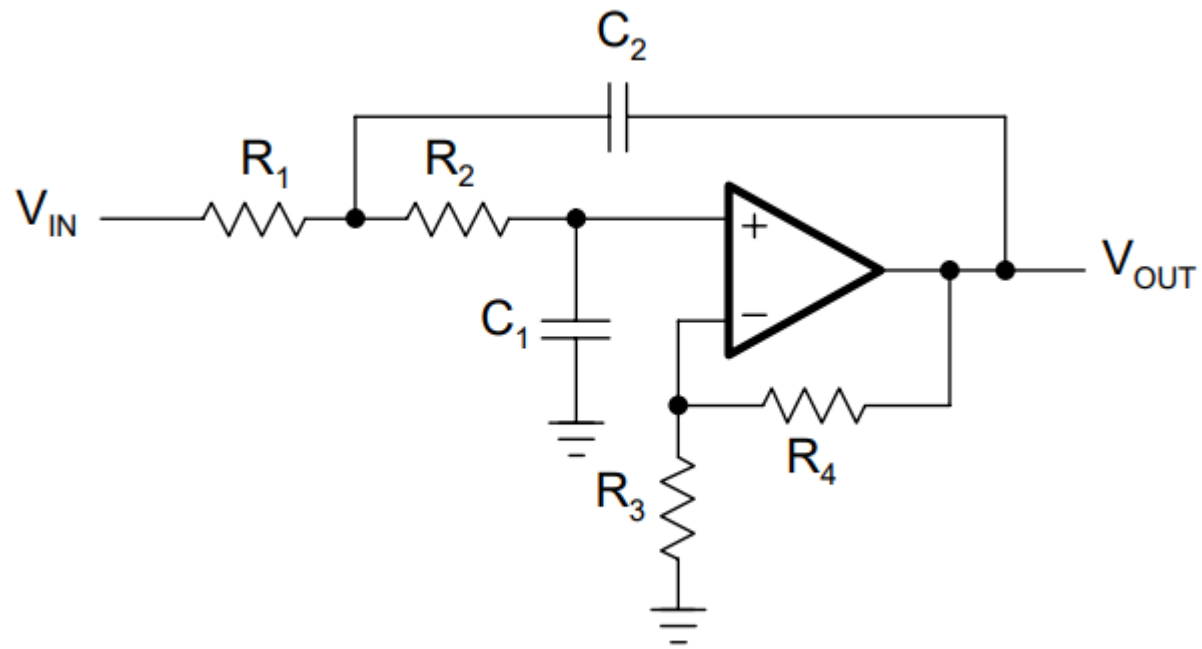
$$R_1 = \frac{a_1}{2\pi f_c C_1} = \frac{0.756}{2\pi \cdot 10^3 \text{ Hz} \cdot 47 \cdot 10^{-9} \text{ F}} = 2.56 \text{ k}\Omega$$

Table 16–4. Bessel Coefficients

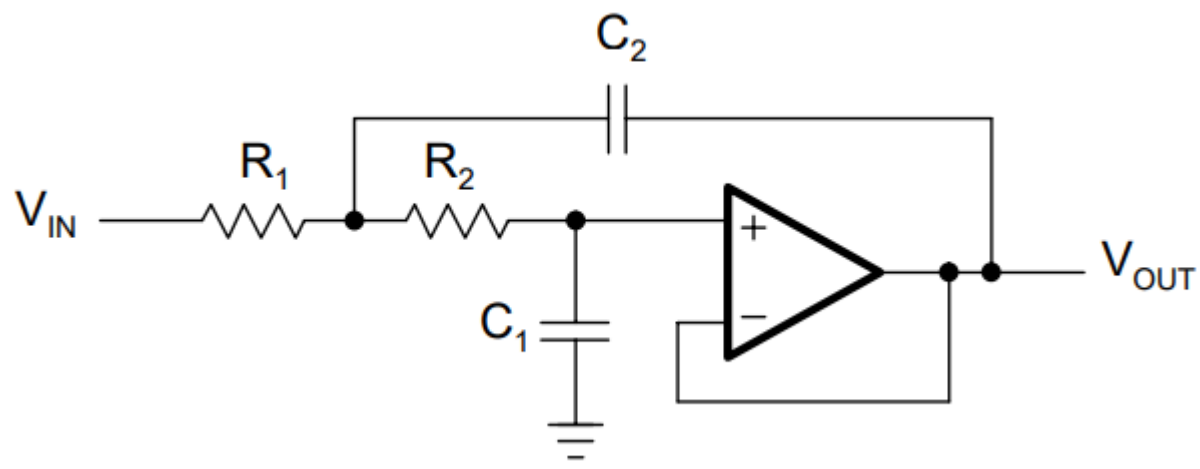
n	i	a_i	b_i	$k_i = f_{Ci} / f_C$	Q_i
1	1	1.0000	0.0000	1.000	—
2	1	1.3617	0.6180	1.000	0.58
3	1	0.7560	0.0000	1.323	—
	2	0.9996	0.4772	1.414	0.69
4	1	1.3397	0.4889	0.978	0.52
	2	0.7743	0.3890	1.797	0.81
5	1	0.6656	0.0000	1.502	—
	2	1.1402	0.4128	1.184	0.56
	3	0.6216	0.3245	2.138	0.92

Фільтри другого порядку

Схема Саллена - Кея



$K=1:$



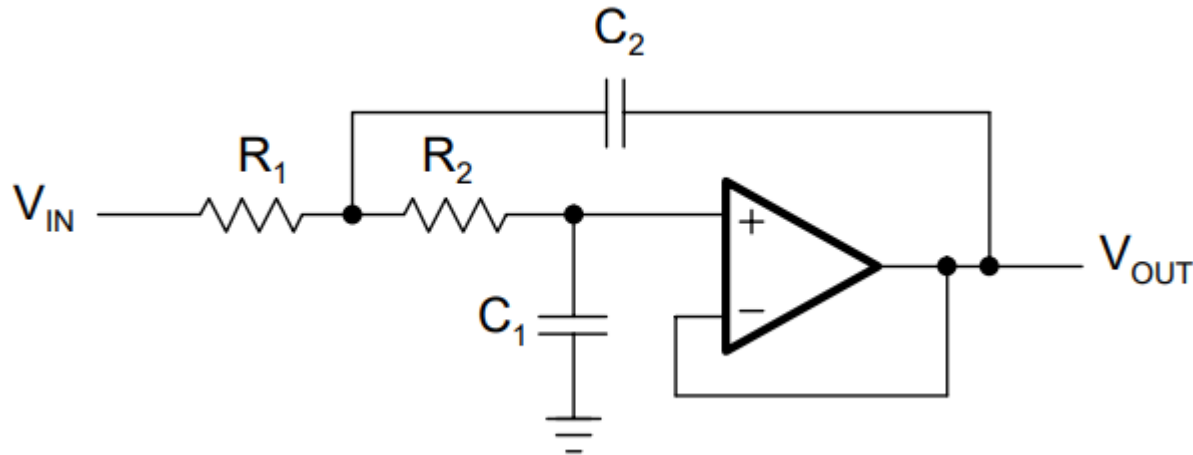
The transfer function of the circuit in Figure 16–15 is:

$$A(s) = \frac{A_0}{1 + \omega_c [C_1(R_1 + R_2) + (1 - A_0) R_1 C_2] s + \omega_c^2 R_1 R_2 C_1 C_2 s^2}$$

For the unity-gain circuit in Figure 16–16 ($A_0=1$), the transfer function simplifies to:

$$A(s) = \frac{1}{1 + \omega_c C_1 (R_1 + R_2) s + \omega_c^2 R_1 R_2 C_1 C_2 s^2}$$

Розрахунок номіналів елементів у схемі Саллена - Кея



$$A_0 = 1$$

$$a_1 = \omega_c C_1 (R_1 + R_2)$$

$$b_1 = \omega_c^2 R_1 R_2 C_1 C_2$$

$$C_2 \geq C_1 \frac{4b_1}{a_1^2}$$

$$R_{1,2} = \frac{a_1 C_2 \mp \sqrt{a_1^2 C_2^2 - 4b_1 C_1 C_2}}{4\pi f_c C_1 C_2}$$

The task is to design a second-order unity-gain Tschebyscheff low-pass filter with a corner frequency of $f_C = 3$ kHz and a 3-dB passband ripple.

From Table 16–9 (the Tschebyscheff coefficients for 3-dB ripple), obtain the coefficients a_1 and b_1 for a second-order filter with $a_1 = 1.0650$ and $b_1 = 1.9305$.

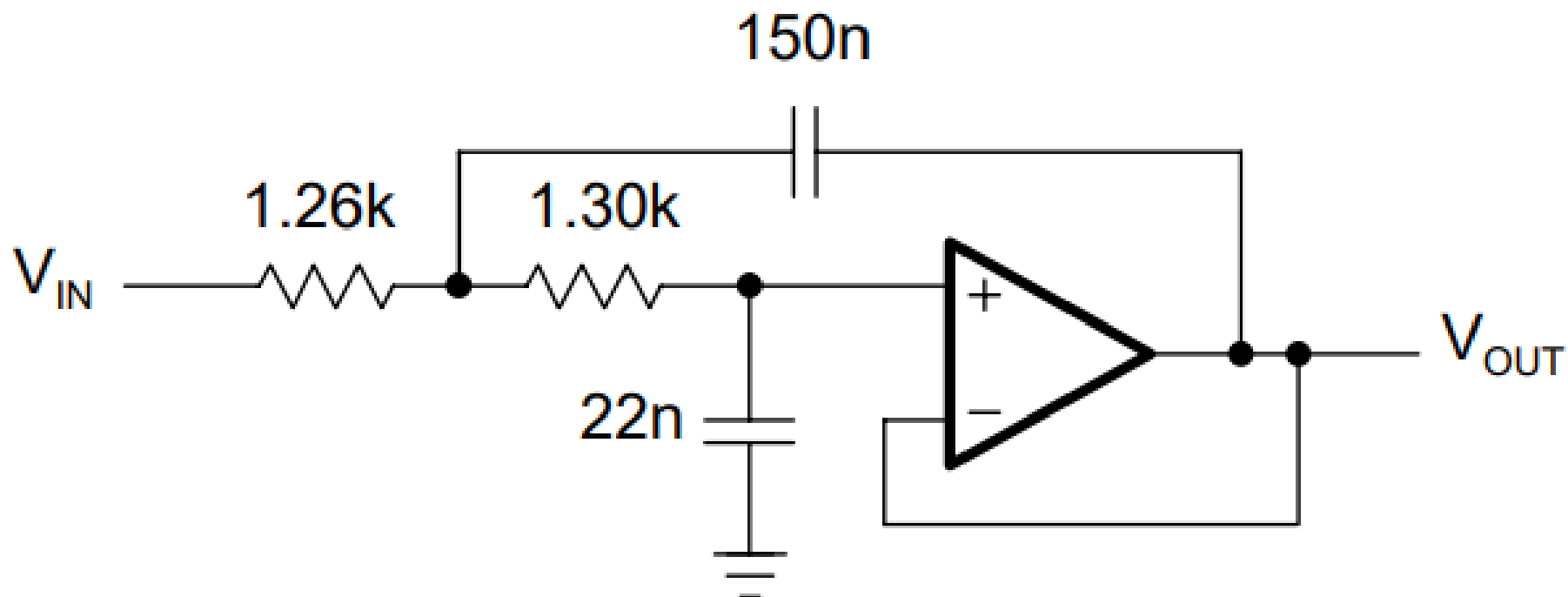
Specifying C_1 as 22 nF yields in a C_2 of:

$$C_2 \geq C_1 \frac{4b_1}{a_1^2} = 22 \cdot 10^{-9} \text{ nF} \cdot \frac{4 \cdot 1.9305}{1.065^2} \cong 150 \text{ nF}$$

Inserting a_1 and b_1 into the resistor equation for R_1 results in:

$$R_1 = \frac{1.065 \cdot 150 \cdot 10^{-9} - \sqrt{(1.065 \cdot 150 \cdot 10^{-9})^2 - 4 \cdot 1.9305 \cdot 22 \cdot 10^{-9} \cdot 150 \cdot 10^{-9}}}{4\pi \cdot 3 \cdot 10^3 \cdot 22 \cdot 10^{-9} \cdot 150 \cdot 10^{-9}} = 1.26 \text{ k}\Omega$$

$$R_2 = \frac{1.065 \cdot 150 \cdot 10^{-9} + \sqrt{(1.065 \cdot 150 \cdot 10^{-9})^2 - 4 \cdot 1.9305 \cdot 22 \cdot 10^{-9} \cdot 150 \cdot 10^{-9}}}{4\pi \cdot 3 \cdot 10^3 \cdot 22 \cdot 10^{-9} \cdot 150 \cdot 10^{-9}} = 1.30 \text{ k}\Omega$$



ФНЧ Саллена-Кея з регульованим коефіцієнтом підсилення

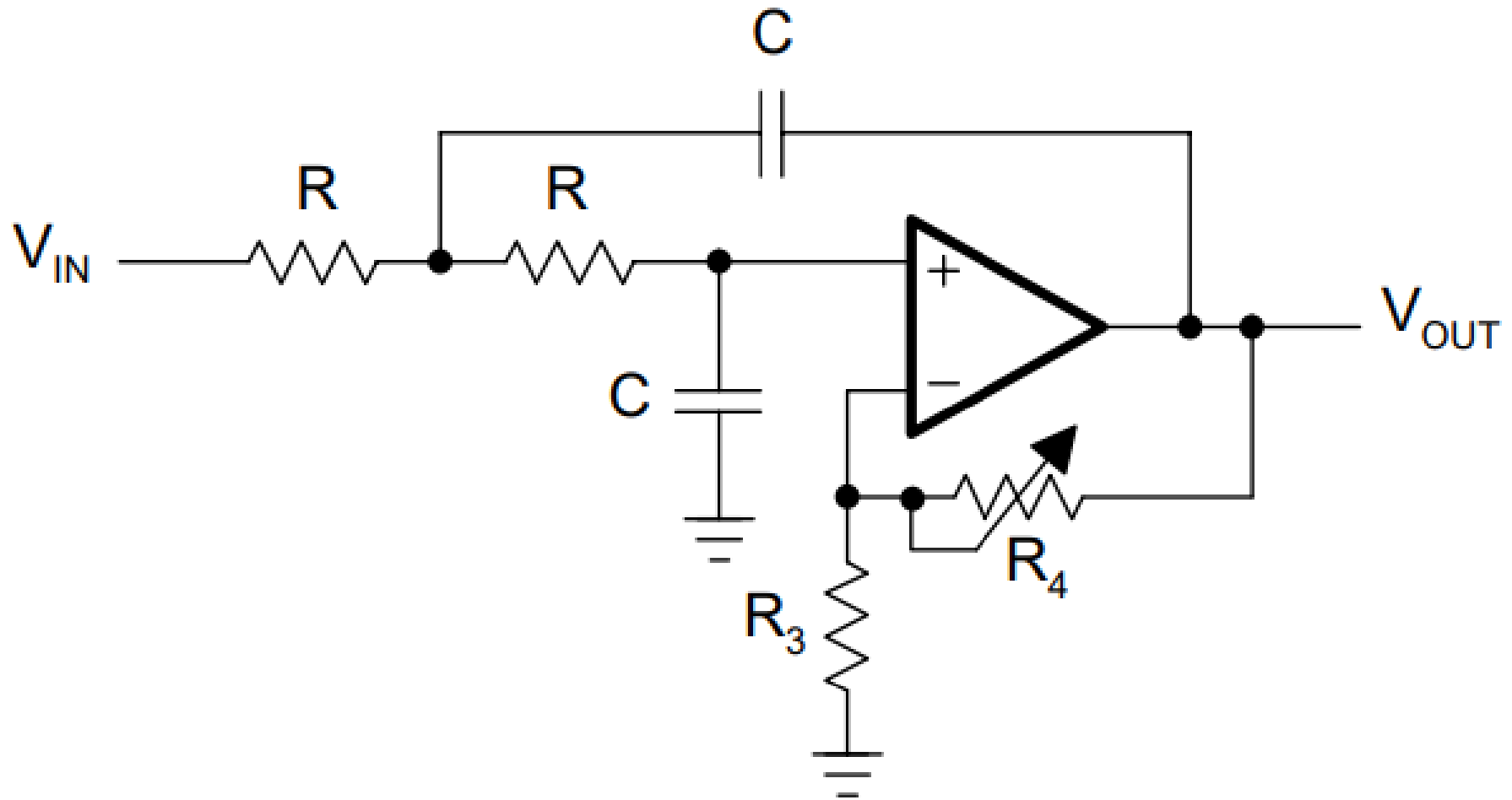
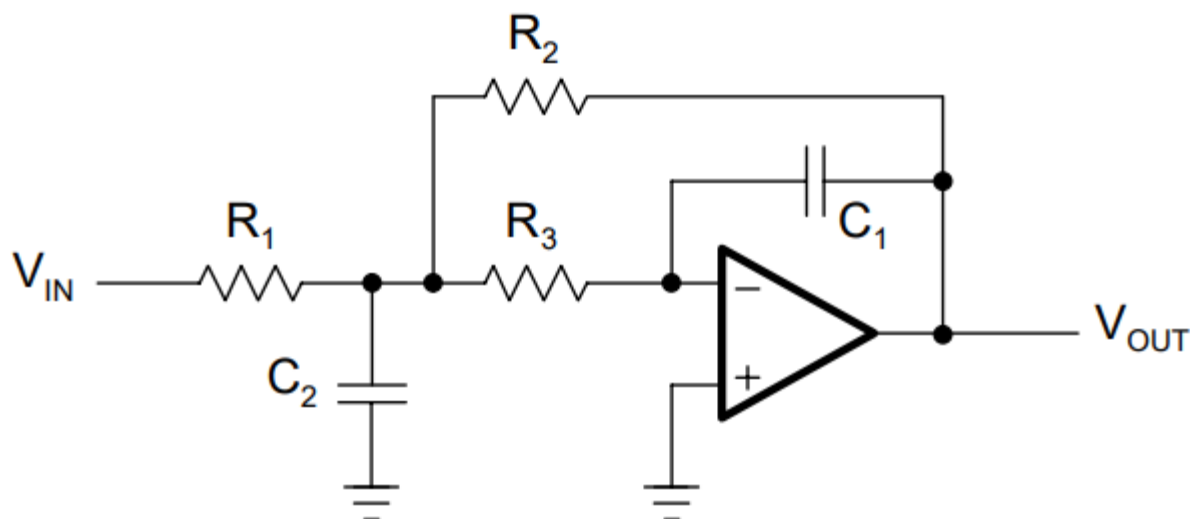


Схема з багатопетлевим зворотним зв'язком



$$A(s) = - \frac{\frac{R_2}{R_1}}{1 + \omega_c C_1 \left(R_2 + R_3 + \frac{R_2 R_3}{R_1} \right) s + \omega_c^2 C_1 C_2 R_2 R_3 s^2}$$

Розрахунок схеми з багатопетлевим зворотним зв'язком

$$A_0 = -\frac{R_2}{R_1}$$

$$a_1 = \omega_c C_1 \left(R_2 + R_3 + \frac{R_2 R_3}{R_1} \right)$$

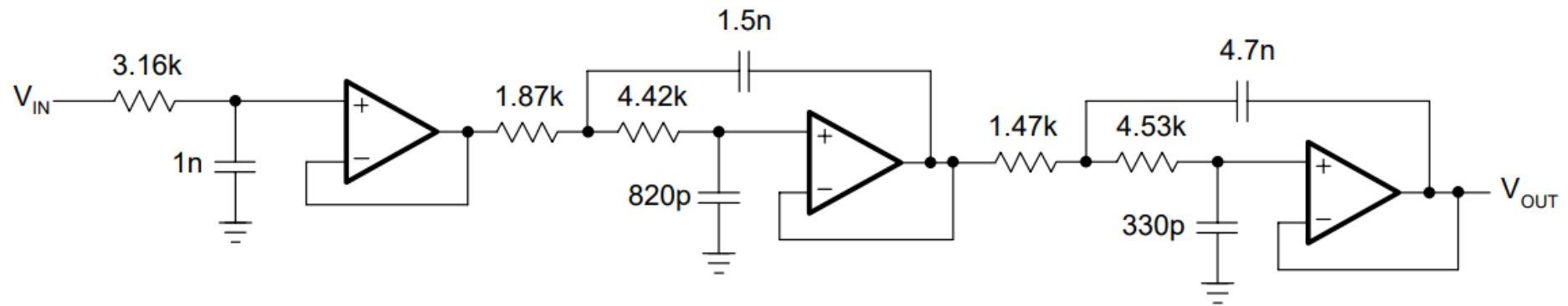
$$b_1 = \omega_c^2 C_1 C_2 R_2 R_3$$

$$R_2 = \frac{a_1 C_2 - \sqrt{a_1^2 C_2^2 - 4b_1 C_1 C_2 (1 - A_0)}}{4\pi f_c C_1 C_2}$$

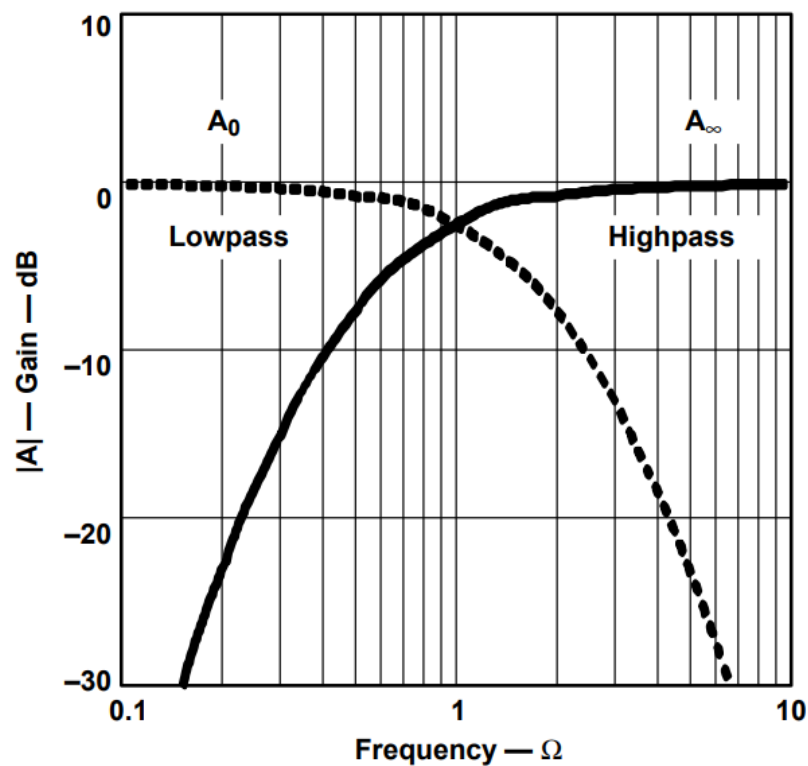
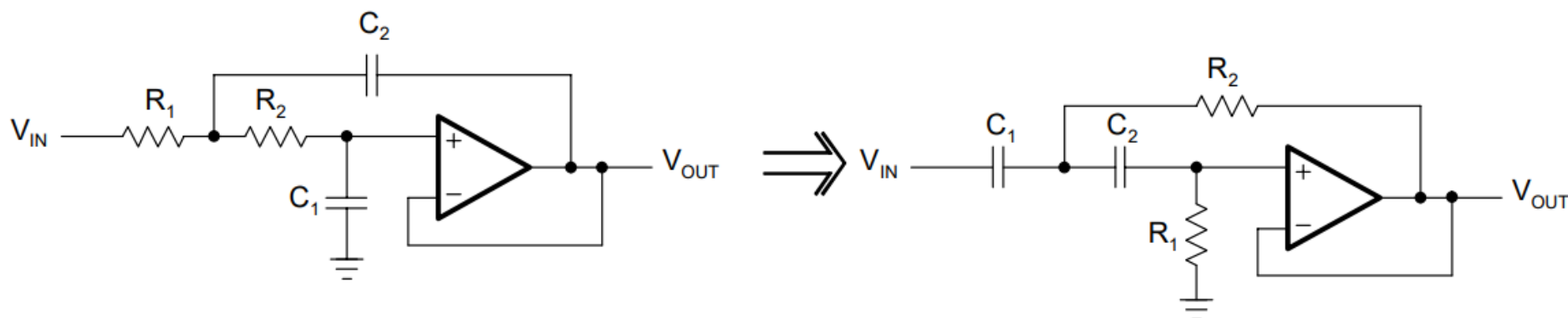
$$R_1 = \frac{R_2}{-A_0}$$

$$R_3 = \frac{b_1}{4\pi^2 f_c^2 C_1 C_2 R_2}$$

$$C_2 \geq C_1 \frac{4b_1 (1 - A_0)}{a_1^2}$$

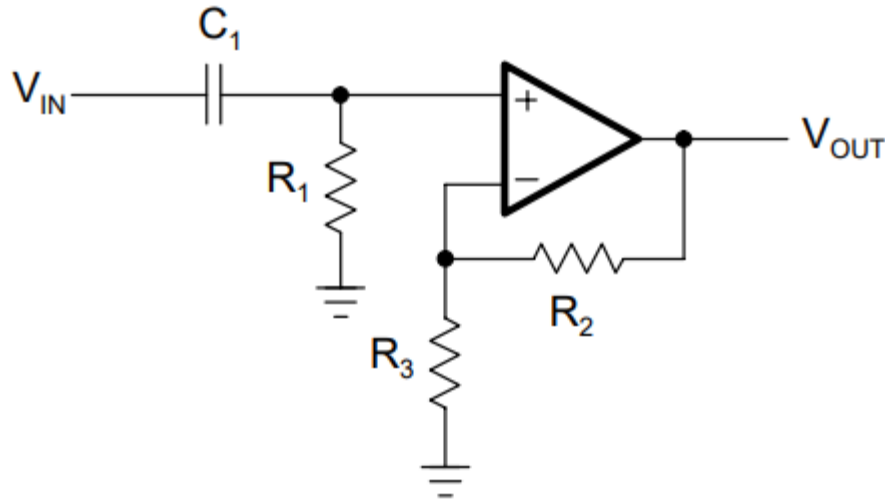


Перехід від ФНЧ до ФВЧ



ФВЧ першого порядку

Неінвертуюча схема



$$a_1 = \frac{1}{\omega_c R_1 C_1}$$

$$R_1 = \frac{1}{2\pi f_c a_1 C_1}$$

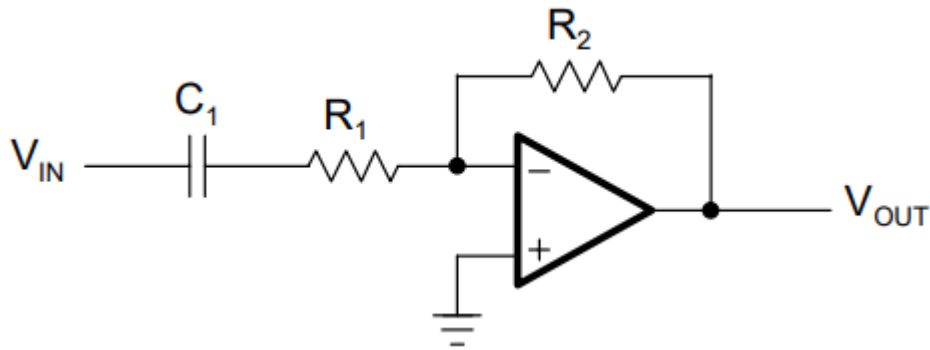
$$A(s) = \frac{1 + \frac{R_2}{R_3}}{1 + \frac{1}{\omega_c R_1 C_1} \cdot \frac{1}{s}}$$

$$A_\infty = 1 + \frac{R_2}{R_3}$$

$$R_2 = R_3(A_\infty - 1)$$

ФВЧ першого порядку

Інвертуюча схема



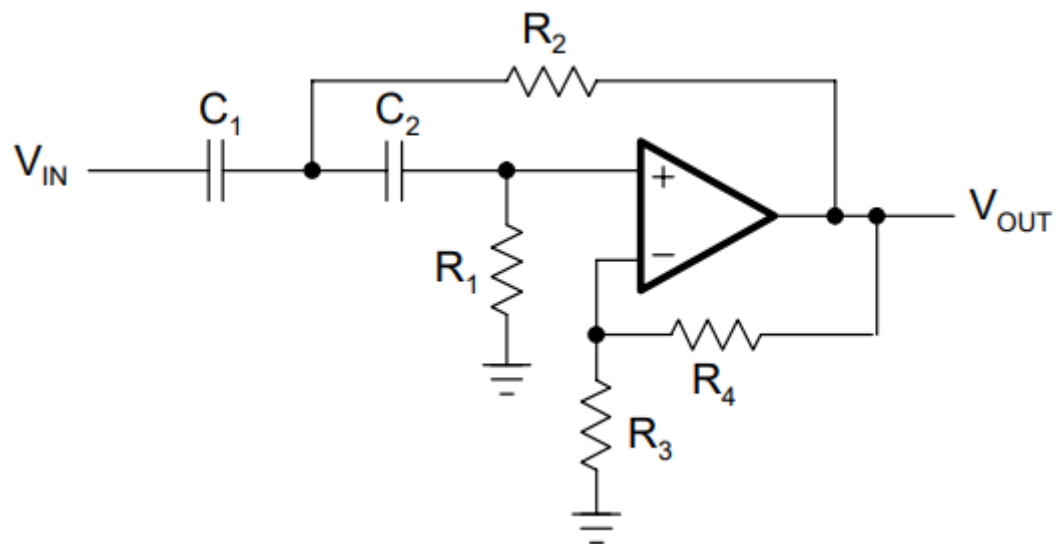
$$a_1 = \frac{1}{\omega_c R_1 C_1}$$

$$R_1 = \frac{1}{2\pi f_c a_1 C_1}$$

$$A(s) = - \frac{\frac{R_2}{R_1}}{1 + \frac{1}{\omega_c R_1 C_1} \cdot \frac{1}{s}}$$

$$R_2 = - R_1 A_\infty$$

$$A_\infty = - \frac{R_2}{R_1}$$

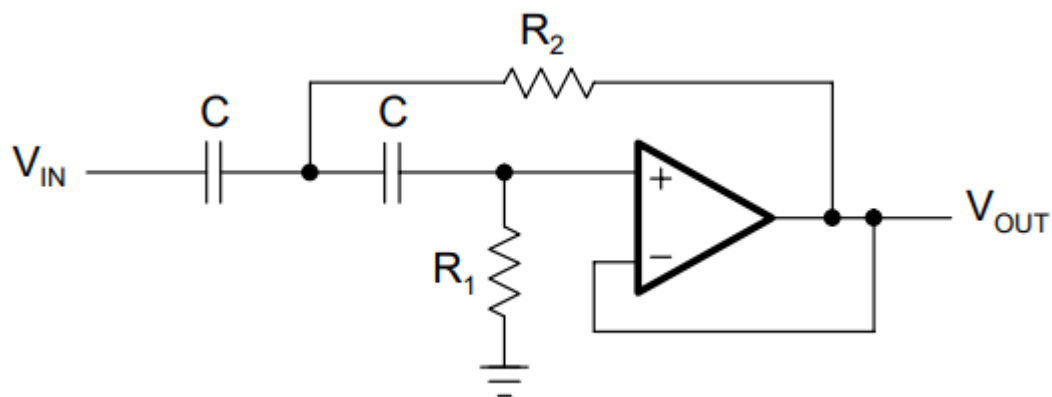


$$A_{\infty} = 1$$

$$a_1 = \frac{2}{\omega_c R_1 C}$$

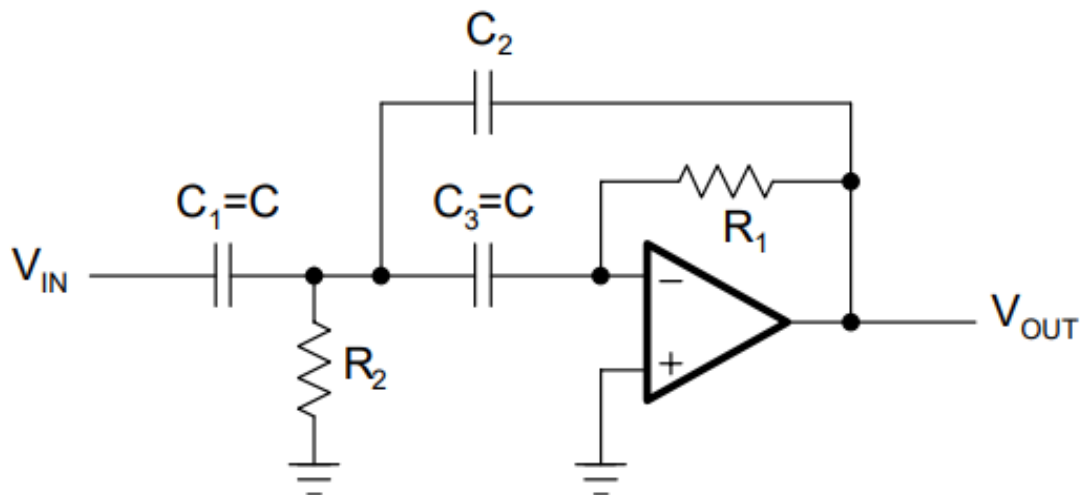
$$b_1 = \frac{1}{\omega_c^2 R_1 R_2 C^2}$$

K=1:



$$R_1 = \frac{1}{\pi f_c C a_1}$$

$$R_2 = \frac{a_1}{4\pi f_c C b_1}$$



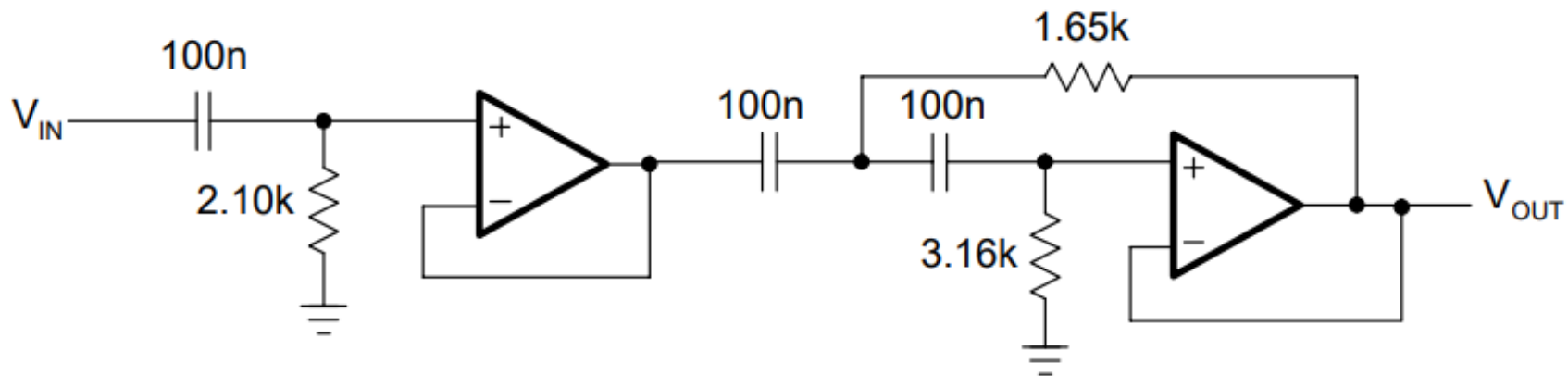
$$A_{\infty} = \frac{C}{C_2}$$

$$a_1 = \frac{2C + C_2}{\omega_c R_1 C C_2}$$

$$b_1 = \frac{2C + C_2}{\omega_c R_1 C C_2}$$

$$R_1 = \frac{1 - 2A_{\infty}}{2\pi f_c \cdot C \cdot a_1}$$

$$R_2 = \frac{a_1}{2\pi f_c \cdot b_1 C_2 (1 - 2A_{\infty})}$$



Далі буде...

...Активні фільтри 4.3. Смугові фільтри