

Analog Electronics Application

08.01.2026

Assistant Ibrahim AYDIN

tonozdayim.com/@Zedeleyici31

Contents

- Constant-gain Multiplier
- Multiple-stage Gains
- Voltage Subtraction
- Low-pass Filter
- High-pass Filter
- Bandpass Filter
- Advices

tonozdayim.com/@Zedeleyici31

LOW-FREQUENCY RESPONSE—BJT

$$A = -\frac{R_f}{R_1}$$

invert

$$A = 1 + \frac{R_f}{R_1}$$

non-inverting

Voltage Summing

$$V_o = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right)$$

Voltage Subtraction

$$V_o = \frac{R_3}{R_1 + R_3}\frac{R_2 + R_4}{R_2}V_1 - \frac{R_4}{R_2}V_2$$

ACTIVE FILTERS

$$A_v = 1 + \frac{R_F}{R_G}$$

High

$$f_{OL} = \frac{1}{2\pi R_1 C_1}$$

Same

$$f_{OH} = \frac{1}{2\pi R_1 C_1}$$

tonozdayim.com/@Zedeleyici31



tonozdayim.com/@Zedeleyici31

Constant-gain Multiplier

EXAMPLE 11.1 Determine the output voltage for the circuit of Fig. 11.2 with a sinusoidal input of 2.5 mV.

$$A = -\frac{R_f}{R_1}$$

$$A = -\frac{200}{2} = -100$$

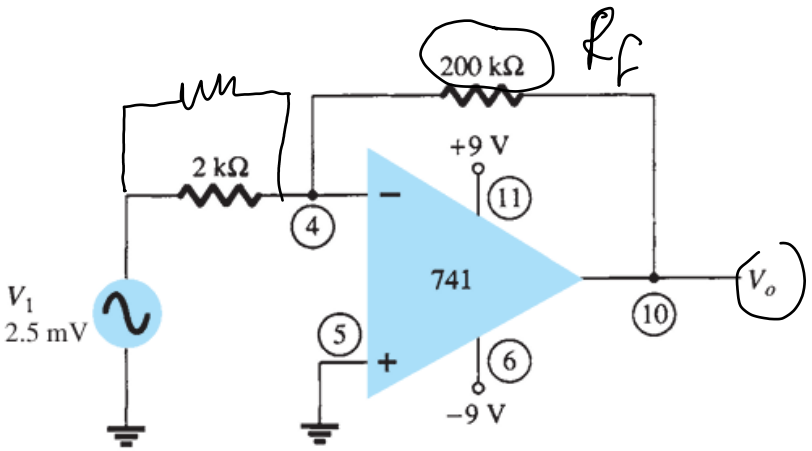
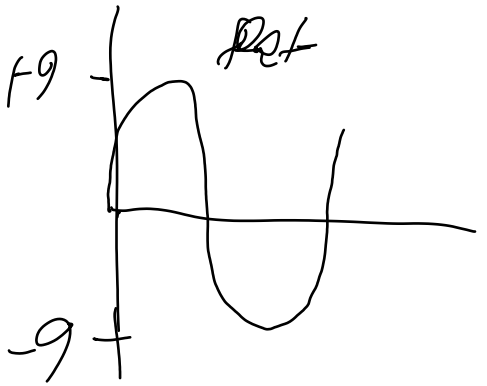


FIG. 11.2



$$V_o = A \cdot V_i = -100 \cdot (2{,}5mV)$$

$$= -0{,}25V$$

if it non-inverting

$$A = 1 + \frac{R_f}{R_1} = 101$$

$$V_o = 101 \cdot (2{,}5mV) = 0{,}252V$$

tonozdayim.com/@Zedeleyici31



tonozdayim.com/@Zedeleyici31

Multiple-Stage Gains

EXAMPLE 11.3 Calculate the output voltage using the circuit of Fig. 11.5 for resistor components of value $R_f = 470\,\text{k}\Omega$, $R_1 = 4.3\,\text{k}\Omega$, $R_2 = 33\,\text{k}\Omega$, and $R_3 = 33\,\text{k}\Omega$ for an input of 80 μV.

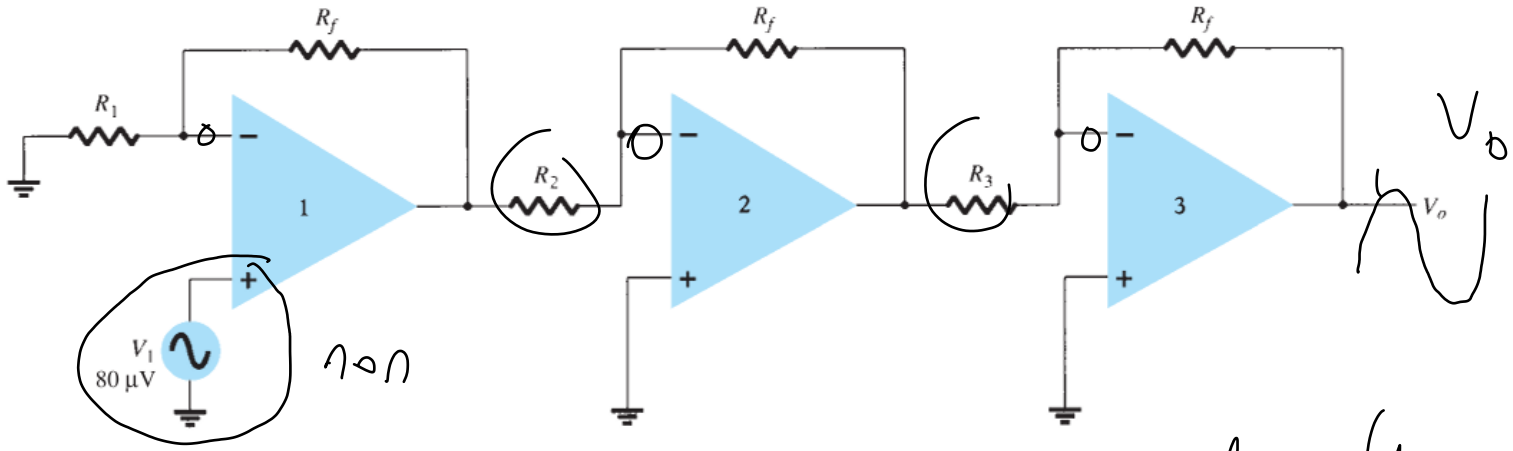


FIG. 11.5

$A_T = A_1 \cdot A_2 \cdot A_3$

$V_o = A_T \cdot V_i$ $\quad \frac{-R_f}{R_1}$

$A_T = \left(1 + \frac{R_f}{R_1}\right)\left(-\frac{R_f}{R_2}\right)\left(-\frac{R_f}{R_3}\right)$

$A_T = 22.2 \times 10^3$

$V_o = A V_i = 22.2 \times 10^3 (80 \times 10^{-6}) = \left(1 + \left(\frac{470}{4.3}\right)\right)\left(-\frac{470}{33}\right)$

$\approx 1.78\,V$ $\quad = 110.3 \cdot (14.2$

tonozdayim.com/@Zedeleyici31

Multiple-Stage Gains

tonozdayim.com/@Zedeleyici31



tonozdayim.com/@Zedeleyici31

Voltage Subtraction

EXAMPLE 11.8 Determine the output voltage for the circuit of Fig. 11.12.

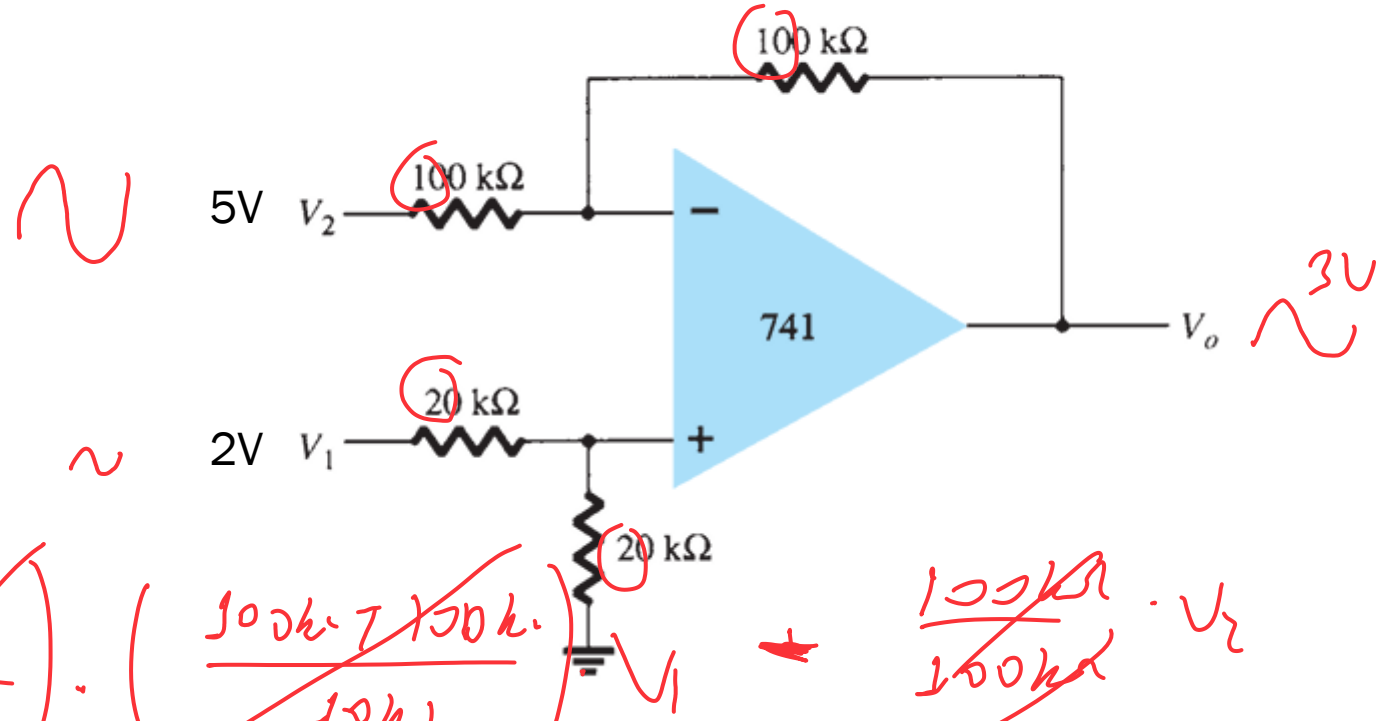


FIG. 11.12

$$V_o = \left(\frac{20k}{10}\right)\cdot\left(\frac{100k \parallel 100k}{10k}\right)V_1 + \frac{100k}{100k}\cdot V_2$$

$$V_o = V_1 - V_2 = 3V$$

tonozdayim.com/@Zedeleyici31

Voltage Subtraction

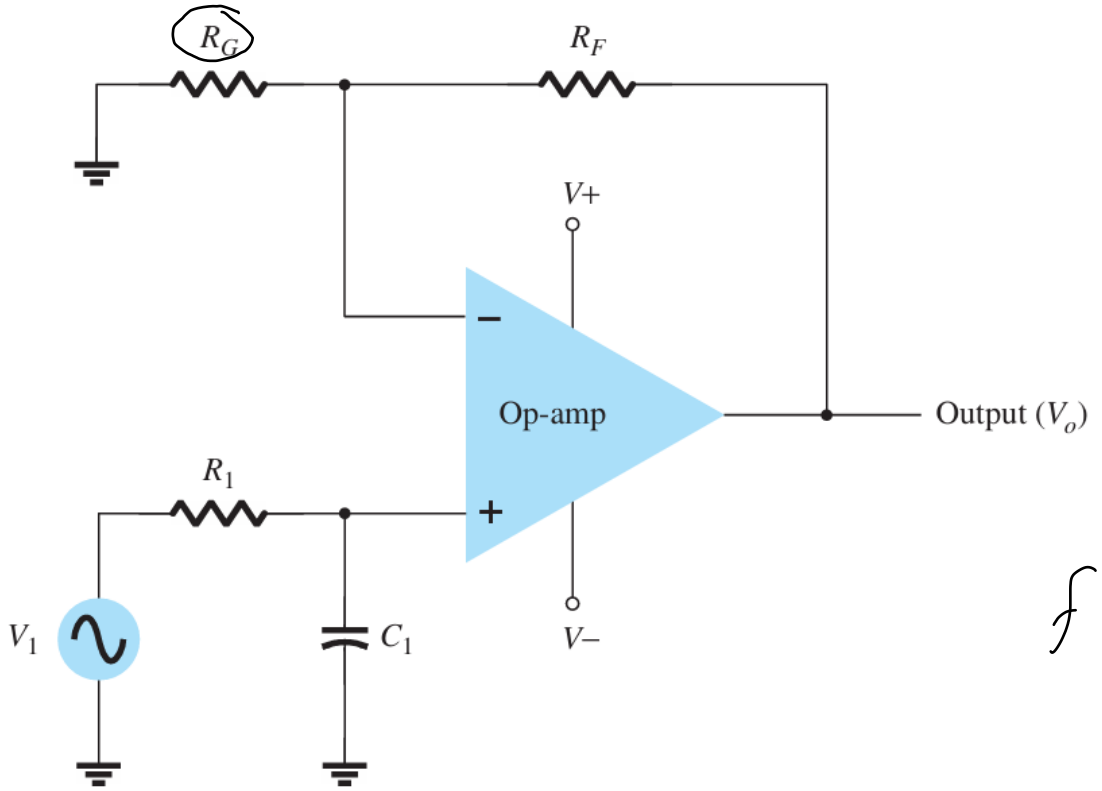
tonozdayim.com/@Zedeleyici31



tonozdayim.com/@Zedeleyici31

Low-pass Filter

EXAMPLE 11.12 Calculate the cutoff frequency of a first-order low-pass filter for $R_1 = 1.2\,\text{k}\Omega$ and $C_1 = 0.02\,\mu\text{F}$.



$$A = -\frac{R_f}{R_G}$$

$$f_{OH} = \frac{1}{2\pi R_1 \cdot C_1}$$

$$f_{OH} = \frac{1}{2\pi \cdot (1{,}2 \times 10^{3})(0{,}02 \times 10^{-6})}$$

$$= 6{,}63\ \text{kHz}$$

tonozdayim.com/@Zedeleyici31

Low-pass Filter



tonozdayim.com/@Zedeleyici31

High-pass Filter

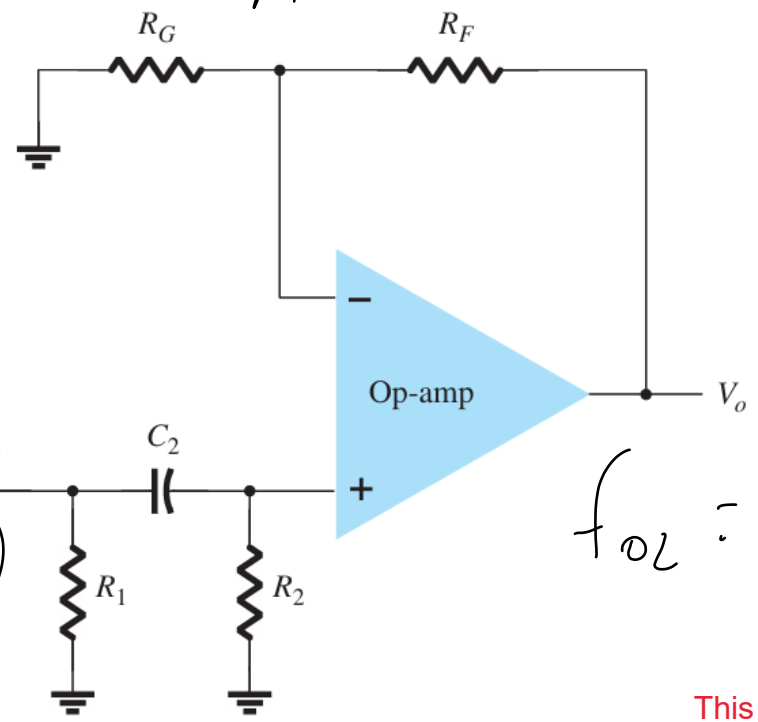
EXAMPLE 11.13 Calculate the cutoff frequency of a second-order high-pass filter as in Fig. 11.33b for $R_1 = R_2 = 2.1\ \text{k}\Omega$, $C_1 = C_2 = 0.05\ \mu\text{F}$, and $R_G = 10\ \text{k}\Omega$, $R_F = 50\ \text{k}\Omega$.

$A = 1 + \frac{R_F}{R_G}$

$= 1 + \frac{50\text{k}\Omega}{10\text{k}\Omega} = 6$

$f_{OL} = \frac{1}{2\pi (2.1\times10^{3})\cdot(0.05\times10^{-6})}$

$f_{OL} = 1.5\text{kHz}$



(b)

$f_{OL} = \frac{1}{2\pi R C_T}$

$f_{OL} = \frac{1}{2\pi \cdot R_1 // R_2 \left(\frac{1}{C_1} + \frac{1}{C_2}\right)}$

This is an incorrect statement. If there is a second-order filter, in this case the formula is calculated twice separately and the largest value is taken for the high-pass filter

$f_{OL} =$

tonozdayim.com/@Zedeleyici31

High-pass Filter

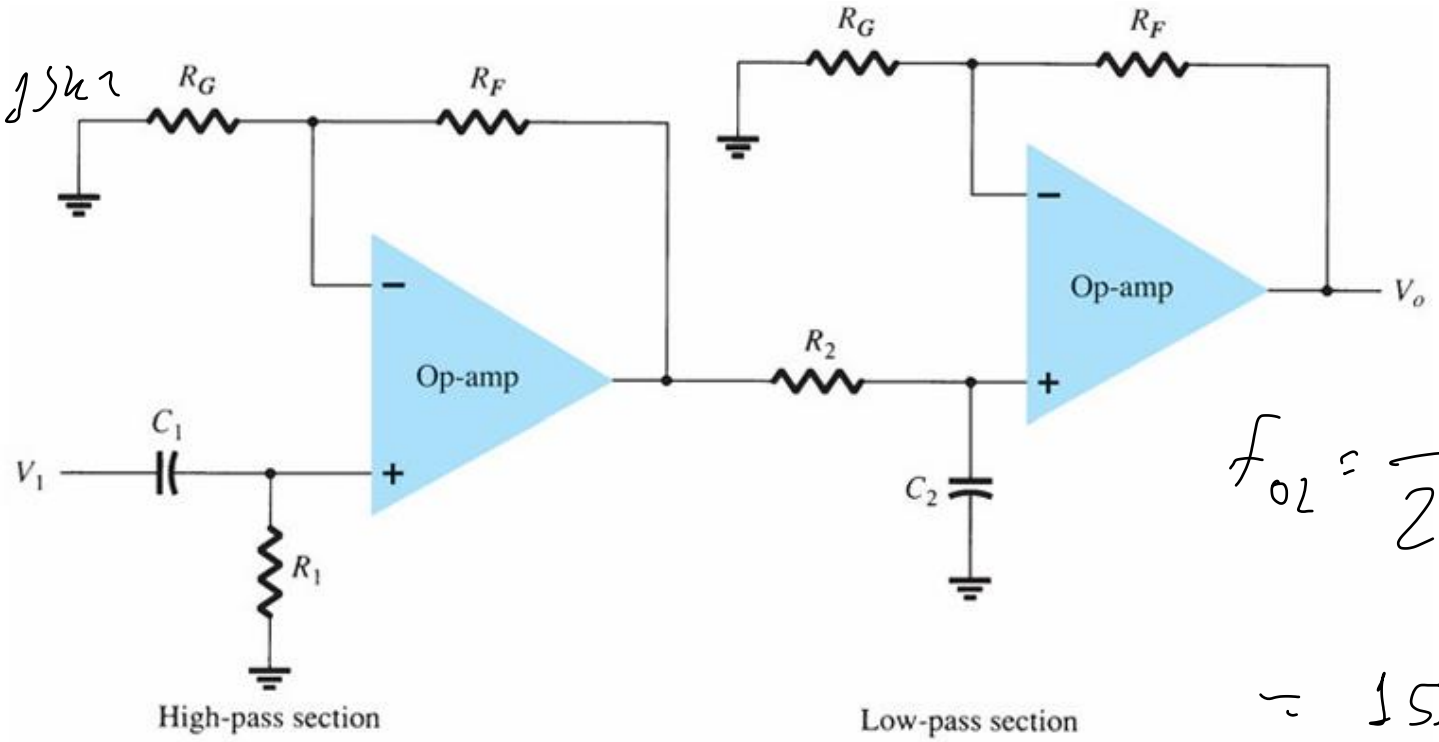
tonozdayim.com/@Zedeleyici31

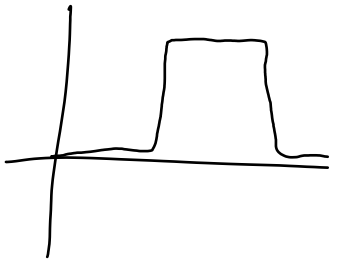


tonozdayim.com/@Zedeleyici31

Bandpass Filter

EXAMPLE 11.14 Calculate the cutoff frequencies of the bandpass filter circuit of Fig. 11.34 with $R_1 = R_2 = 10\,\text{k}\Omega$, $C_1 = 0.1\,\mu\text{F}$, and $C_2 = 0.002\,\mu\text{F}$.





$f_{oL} = \frac{1}{2\pi(10\times10^3)\cdot(0.1\times10^{-6})}$

$= 159.15\,\text{kHz}$

$f_{oH} = 7.96\,\text{kHz} = f_{oH} = \frac{1}{2\pi(10\times10^3)\cdot(0.002\times10^{-6})}$

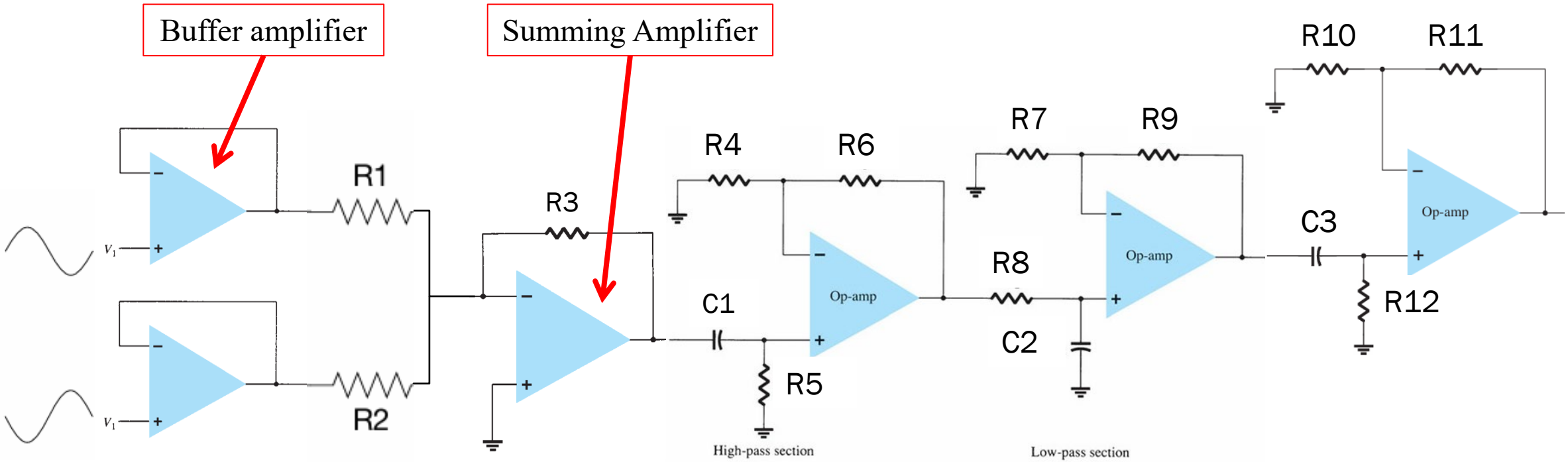
tonozdayim.com/@Zedeleyici31

Bandpass Filter



tonozdayim.com/@Zedeleyici31

Advices



tonozdayim.com/@Zedeleyici31

Advices

Solution:

For example, let the variables listed below be given.

Parameter	Value
V1	20 mV
V2	30 mV
R1	10 kΩ
R2	10 kΩ
R3	50 kΩ
C1	0.1 µF
R5	1.6 kΩ
R4	10 kΩ
R6	10 kΩ
R8	1.6 kΩ
C2	0.01µF
R7	10 kΩ
R9	10 kΩ
C3	0.1pF
R12	10 kΩ
R10	40 kΩ

Q1: Determine the High-Pass frequency (f_{OL}) of the system.
Q2: Determine the Low-Pass frequency (f_{OH}) of the system.
Q3: Calculate the final output voltage (Vo) in Volts.

Solution of Q1:

$$f_{OL} = \frac{1}{2\pi R_1 C_1}$$

$$f_{OL} = \frac{1}{2\pi(1.6 \times 10^3\,\Omega)(0.1 \times 10^{-6}\,\mathrm{F})}$$

$$f_{OL} = \frac{1}{2\pi(1.6 \times 10^{-4})}$$

$$f_{OL} \approx \frac{1}{0.0010053}$$

$$f_{OL} \approx \mathbf{995}\ \mathrm{Hz}$$

tonozdayim.com/@Zedeleyici31

Advices

Solution of Q2:

$$f_{OH} = \frac{1}{2\pi R_1 C_1}$$

$$f_{OH} = \frac{1}{2\pi(1.6 \times 10^3\,\Omega)(0.01 \times 10^{-6}\,\mathrm{F})}$$

$$f_{OH} = \frac{1}{2\pi(1.6 \times 10^{-5})}$$

$$f_{OH} \approx \frac{1}{0.00010053}$$

$$f_{OH} \approx \mathbf{9947}\,\mathrm{Hz} \quad (\approx 9.95\,\mathrm{kHz})$$

tonozdayim.com/@Zedeleyici31

Advices

Solution of Q3:

For an inverting summing amplifier:

$$V_{sum} = -\left(\frac{R_F}{R_1}v_{in1} + \frac{R_F}{R_2}v_{in2}\right)$$

Substituting the values ($R_F = R_3 = 50\text{k}\Omega$):

$$V_{sum} = -\left(\frac{50\text{k}}{10\text{k}}(20\text{mV}) + \frac{50\text{k}}{10\text{k}}(30\text{mV})\right)$$
$$V_{sum} = -(5 \cdot 20 + 5 \cdot 30) = -(100 + 150)$$
$$V_{sum} = \mathbf{-250}\,\text{mV}$$

Non-inverting amplifier gain:

$$A_{v1} = 1 + \frac{R_F}{R_G} = 1 + \frac{R_6}{R_4} = 1 + \frac{10\text{k}}{10\text{k}} = \mathbf{2}$$

Non-inverting amplifier gain:

$$A_{v2} = 1 + \frac{R_F}{R_G} = 1 + \frac{R_9}{R_7} = 1 + \frac{10\text{k}}{10\text{k}} = \mathbf{2}$$

Non-inverting amplifier gain:

$$A_{v3} = 1 + \frac{R_F}{R_G} = 1 + \frac{R_{11}}{R_{10}} = 1 + \frac{40\text{k}}{10\text{k}} = \mathbf{5}$$

$$V_{out} = V_{sum} \times A_{v1} \times A_{v2} \times A_{v3}$$
$$V_{out} = (-250\,\text{mV}) \times 2 \times 2 \times 5$$
$$V_{out} = -250\,\text{mV} \times 20$$
$$V_{out} = -5000\,\text{mV}$$
$$V_{out} = \mathbf{-5}\,\text{V}$$

tonozdayim.com/@Zedeleyici31

Thanks

Assistant İbrahim AYDIN

ibrahim.aydin@yildiz.edu.tr



tonozdayim.com/@Zedeleyici31