Electrical Science-2 (15B11EC211)

Unit-3
Operational Amplifier and Filters
Lecture-2

Contents

Non-inverting Amplifier

- Non-inverting amplifier: The input voltage vi is applied directly at the non-inverting input terminal, and resistor R1 is connected between the ground and the inverting terminal.
- A non-inverting amplifier is an op amp circuit designed to provide a positive voltage gain.

Applying KCL at node V1

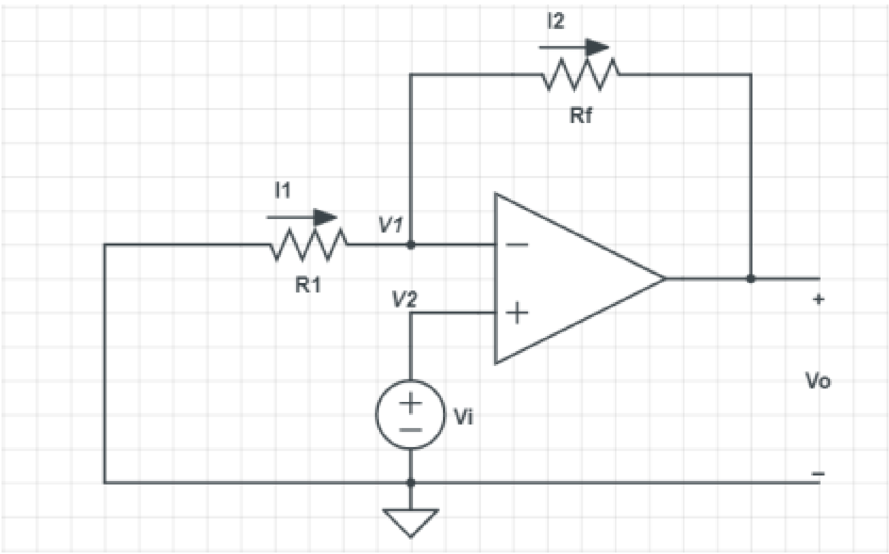
$$I1 = I2$$

$$\frac{0 - V1}{R1} = \frac{V1 - Vo}{Rf}$$

But $V1$= $V2$= Vi for an ideal op amp, since the noninverting terminal is grounded. Hence,

$$-\frac{Vi}{R1} = \frac{Vi - Vo}{Rf}$$

$$Vo = (1 + \frac{Rf}{R1})Vi$$



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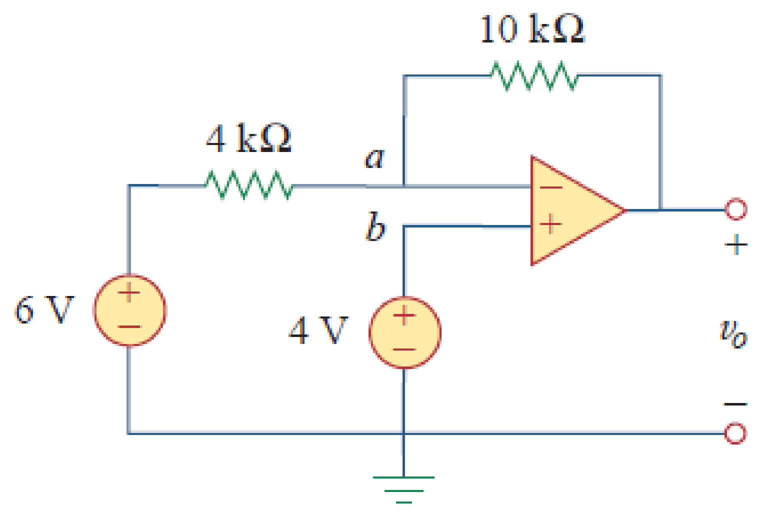
Problem

Q1. Calculate the output voltage of the given figure.



Sol: Applying KCL at Node 'a'

$$\frac{6 - va}{4} = \frac{va - vo}{10}$$

$$But, va = vb = 4V$$

$$\frac{6 - 4}{4} = \frac{4 - vo}{10}$$

$$vo = -1V$$

Ref:1

Summing Amplifier

- Summing amplifier: A summing amplifier is an op amp circuit that combines several inputs and produces an output that is the weighted sum of the inputs.

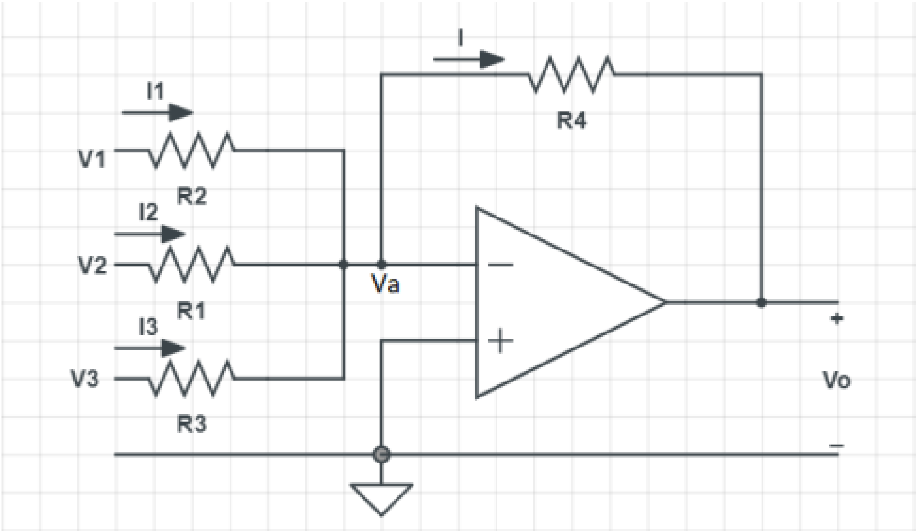
Applying KCL at node Va

$$I1 + I2 + I3 = I$$

$$\frac{V1 - Va}{R2} + \frac{V2 - Va}{R1} + \frac{V3 - Va}{R3} = \frac{Va - Vo}{R4}$$

Note, Va=0 for an ideal op amp, since the noninverting terminal is grounded. Hence,

$$Vo = -(\frac{R4}{R2}V1 + \frac{R4}{R1}V2 + \frac{R4}{R3}V3)$$



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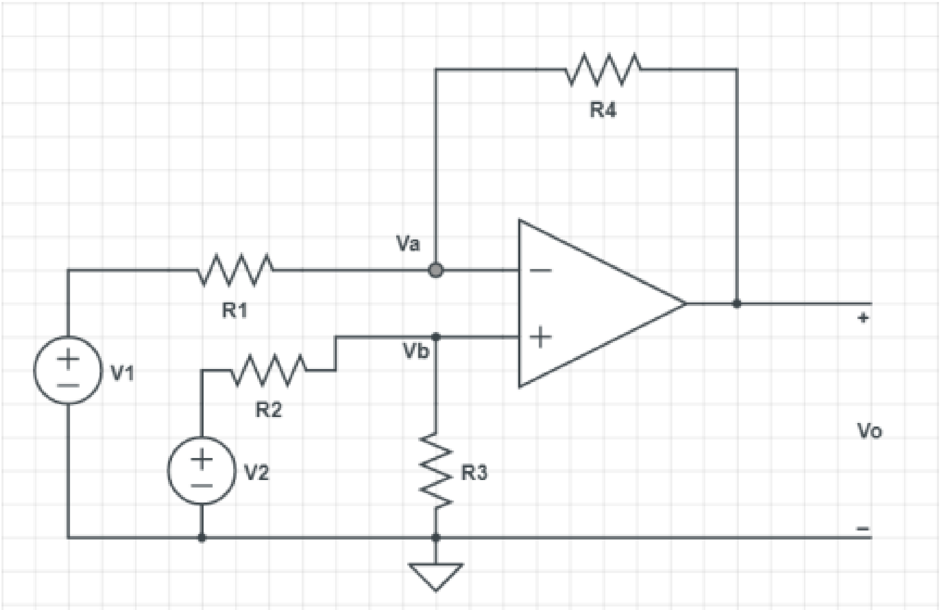
Difference Amplifier

- Difference amplifier: A difference amplifier is a device that amplifies the difference between two inputs but rejects any signals common to the two inputs.

Applying KCL at node Va

$$\frac{V1 - Va}{R1} = \frac{Va - Vo}{R4}$$

$$Vo = \frac{R4}{R1} + 1 \quad Va - \frac{R4}{R1} V1$$



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Applying KCL at node Vb

$$\frac{V2 - Vb}{R2} = \frac{Vb - 0}{R3}$$

$$Vb = \frac{R3}{R3 + R2} V2$$

Note, Va=Vb

$$Vo = \frac{R4}{R1} + 1 \quad \frac{R3}{R3+R2} \; V2 - \frac{R4}{R1} V1$$

Since a difference amplifier must reject a signal common to the amplifier must have the property that $Vo = 0$ when $V1 = V2$.

This property exists when

$$\frac{R1}{R4} = \frac{R2}{R3}$$

If $R1 = R4$ and $R2 = R3$, the difference amplifier becomes a subtractor, with the output

$$V0 = V1 - V2$$

Ref:1

Integrator

- Integrator: An integrator is an op amp circuit whose output is proportional to the integral of the input signal

Applying KCL at node a

$$Ir = Ic$$

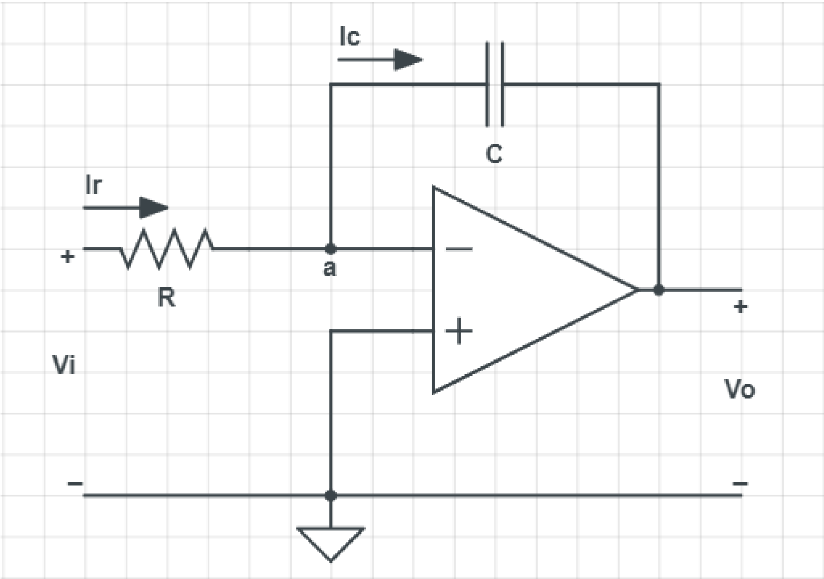
$Note, At\ node\ a\ the\ voltage$ is 0

$$\frac{Vi - 0}{R} = -C\frac{dVo}{dt}$$

$$dVo = -\frac{1}{RC}Vi\ dt$$

$Integrating\ both\ side$

$$Vo = -\frac{1}{RC}\int_0^t Vi(t)dt$$



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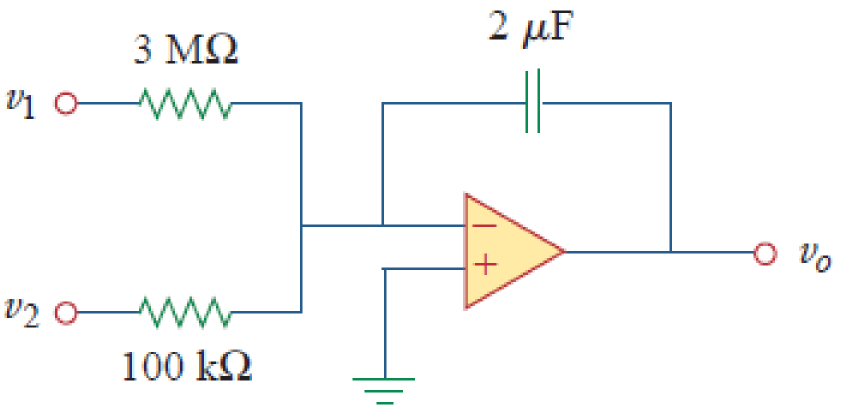
Problem

Q2. If $v1=10cos2t\ mV$ *and* $v2=0.5t\ mV$, find *vo* in the op amp circuit as shown in Figure. Assume that the voltage across the capacitor is initially zero.



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Sol: This is summer integrator

$$vo = -\frac{1}{R_1 C} \int v_1 dt - \frac{1}{R_2 C} \int v_2 dt$$

$$vo = \frac{1}{3 \times 10^6 \times 2 \times 10^{-6}} \int_0^t 10 \cos 2t \; dt$$

$$- \frac{1}{100 \times 10^3 \times 2 \times 10^{-6}} \int_0^t 0.5 \; t \; dt$$

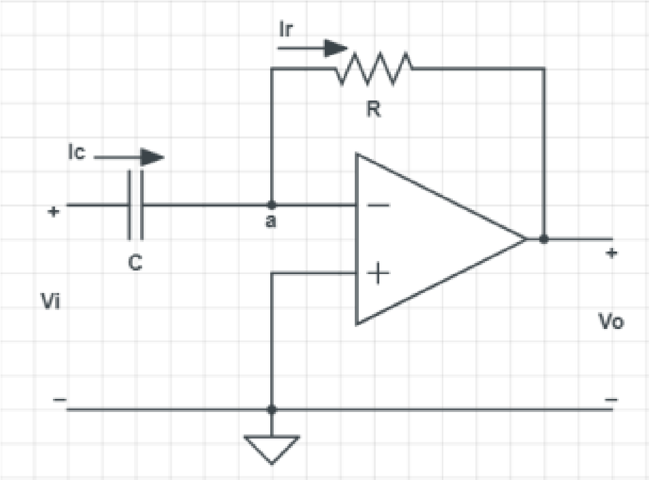
$$vo = -\frac{1}{6}\frac{10}{2} \; sin2t - \frac{1}{0.2}\frac{0.5 \; t^2}{2}$$

$$vo = -0.833 \sin 2t - 1.25 \; t^2$$

Differentiator

- Differentiator: A differentiator is an op amp circuit whose output is proportional to the rate of change of the input signal.

Applying KCL at node a



$$Ic = Ir$$

$Note, At\ node\ a\ the\ voltage$ is 0

$$C\,\frac{d(Vi-0)}{dt} = \frac{0-Vo}{R}$$

$$Vo = -RC\,\frac{dVi}{dt}$$

$showing\ that\ the\ output\ is\ the\ derivative\ of\ the\ inp$

Ref:1

Introduction to Filters

Introduction to Filter

- A filter is a circuit that is designed to pass signals with desired frequencies and reject or attenuate others.
- An electric filter can be used to eliminate unwanted constituents, such as electrical noise, from an electrical signal.
- Filters are the circuits used in radio and TV receivers to allow us to select one desired signal out of a multitude of broadcast signals in the environment.
- There are mainly two types of filters:
  1. Passive filters
  2. Active Filters

Ref:1, 3

Introduction to Filter

- **Passive filters:** The filters constructed using passive elements like inductors, capacitors, and resistors are called passive filters.
- **Active filters:** The filters developed using active *elements* (such as transistors and op amps) in addition to passive elements *R, L,* and *C*, are called active filter.
- The active filters are usually constructed without inductors (only op amps, resistors, and capacitors) because inductors are relatively large and heavy.

Ref:1, 3

Types of Filters

- There are four types of filters whether passive or active:
  1. Lowpass
  2. Highpass
  3. Bandpass
  4. Bandstop

- A lowpass filter passes low frequencies and stops high frequencies, as shown

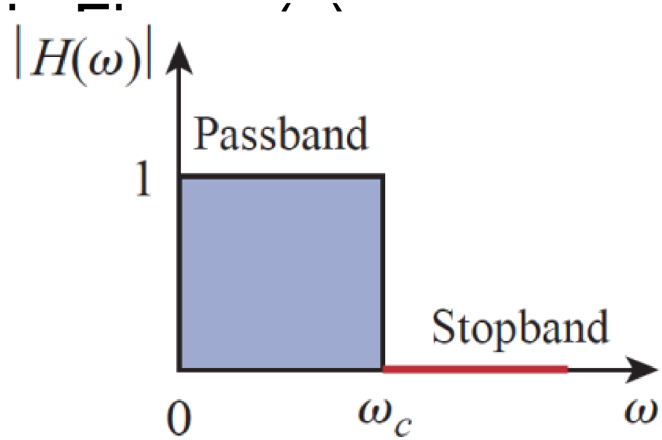


Figure (a)

Ref:1, 3

Types of Filters

- A highpass filter passes high frequencies and rejects low frequencies, as shown in Figure (b).

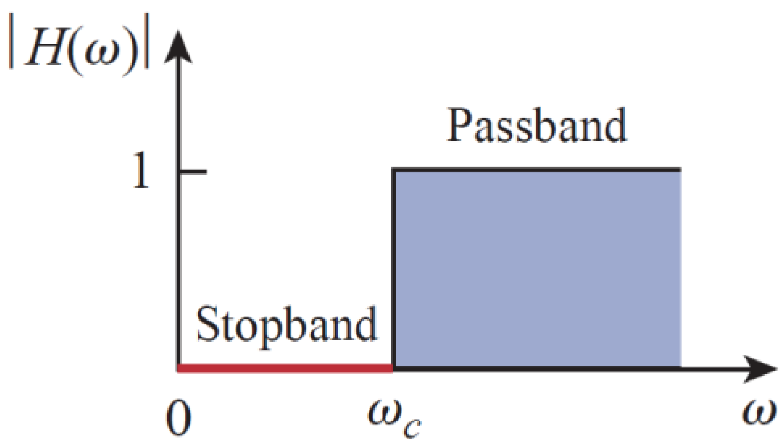


Figure (b)

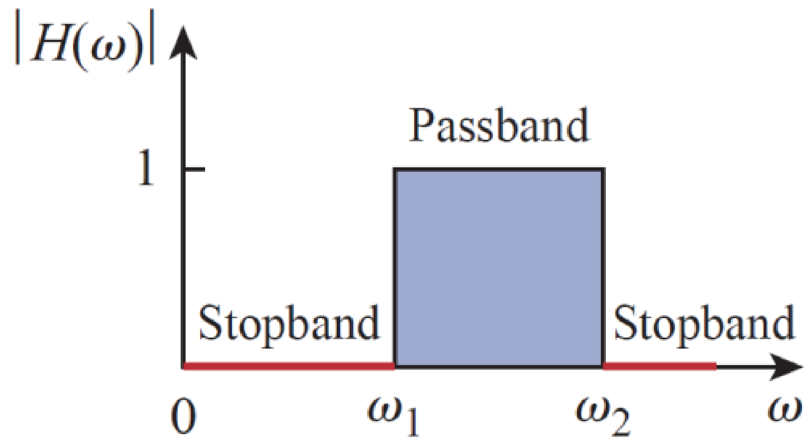


Figure (C)

- A bandpass filter passes frequencies within a frequency band and blocks or attenuates frequencies outside the band, as shown in Figure (C).

Ref:1, 3

Types of Filters

- A bandstop filter passes frequencies outside a frequency band and blocks or attenuates frequencies within the band, as shown in Figure (d).

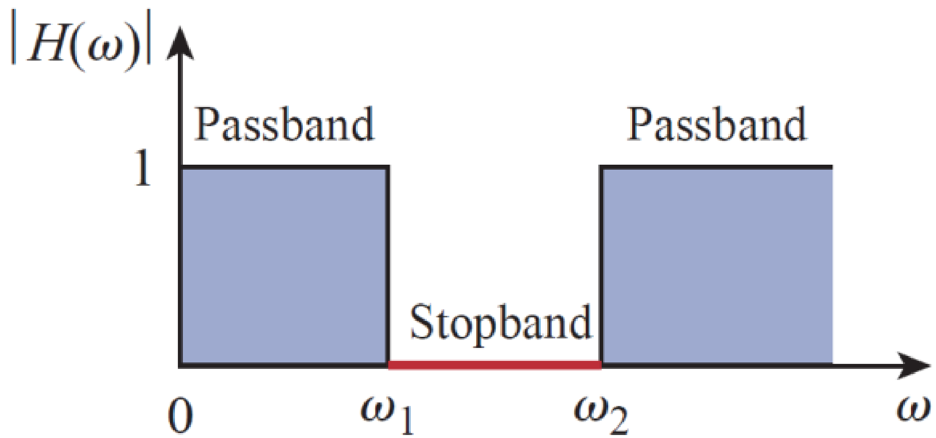


Figure (d)

Ref:1, 3

Order of Filter

- The order, n of a filter is the number of reactive elements (if all are contributing.)
- Order of the filter means the maximum number of delay elements used in the filter circuit.
- A first order filter would have one capacitor or one inductor, that affects the filters frequency response.
- A second order filter would have two capacitors or two inductors, or one capacitor and one inductor, that affects the filter's frequency response.
- There is a trade-off involving the order of the filter. The higher the order, the more accurately the filter frequency response approximates the frequency response of an ideal filter; that's good.
- The higher the filter order, the more complicated the circuit required to build the filter; that's not good.

Ref:1, 3

Reference

1. Charles K. Alexander and Matthew N. O. Sadiku, “Fundamentals of Electric Circuits”, Chapter 19, 4th ed, Mcgraw Hill, 2009
2. Ramakant A. Gayakwad, “Op-Amps and Linear Integrated Circuits”, 4th edition, Pearson, 2000
3. R.C. Dorf and J. A. Svoboda, “Introduction to Electric Circuits”, 9th ed, John Wiley & Sons, 2013