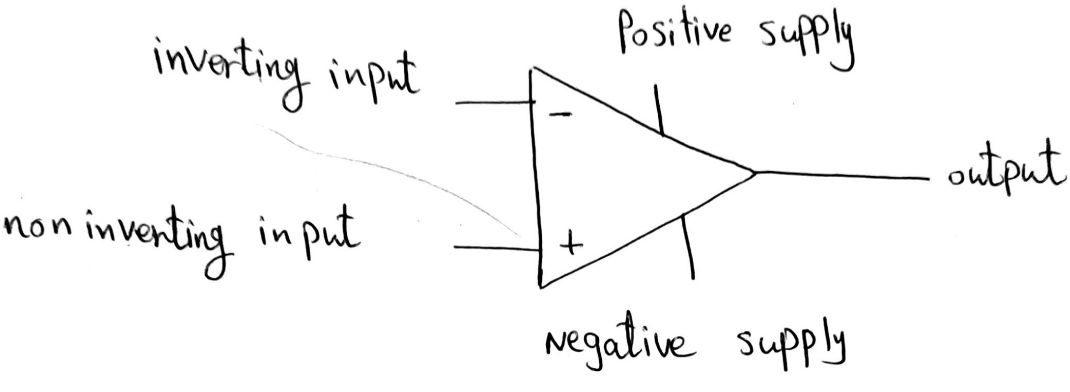
أ. حورية المجراب

دوائر الكترونية 3

operational Amplifiers "op-amp"

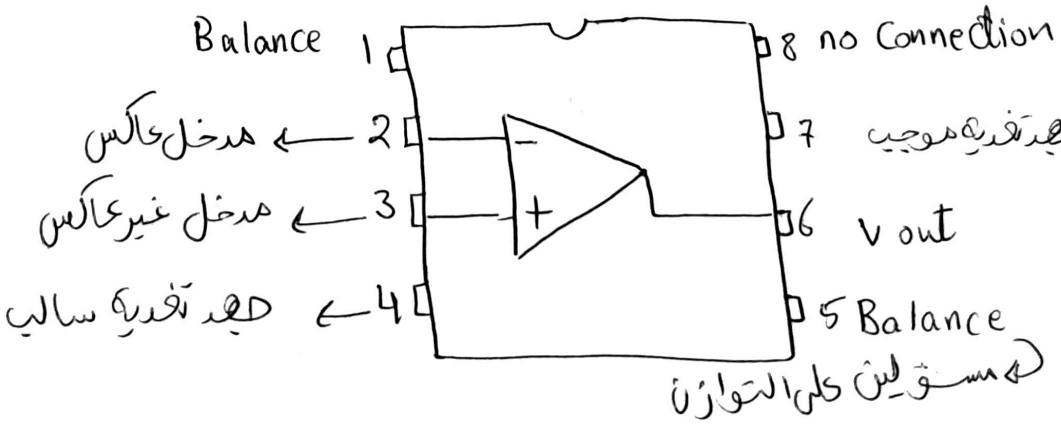


input → X → [A] → out = X·A ⇐ فكرة عمل المكبر

Gain

* المكبر هو قطعة الكترونية تستخدم لتكبير وتضخيم الجهود وبداية تصميمها كان لغرض القيام ببعض العمليات الحسابية وساعد كثيراً في عملية التكبير وبعض التطبيقات الأخرى مثل استخدامه في دوائر المقارنات و المنظمات .

لتشغيل المضخم نحتاج لمصدر جهد للتغذية قادر على اعطاء + و - (V)
بإمكان المكبر أن يكبر الإشارة ويعكس القطبية ويعمل كفلتر وكمقارن



Ideal op-Amp

	قيم عملية	قيم مثالية
A	$10^5 \rightarrow 10^8$	∞
R_i	$10^5 \rightarrow 10^8\ (\Omega)$	∞
R_o	$10 \rightarrow 100\ (\Omega)$	0

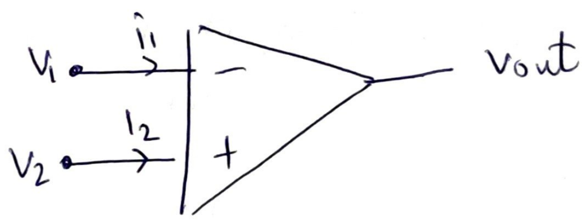
A_{OL}

$\pm V_{CC}$ $\quad 5 \rightarrow 24\ (V)$

$\therefore$ $i_1 = 0$

$i_2 = 0$

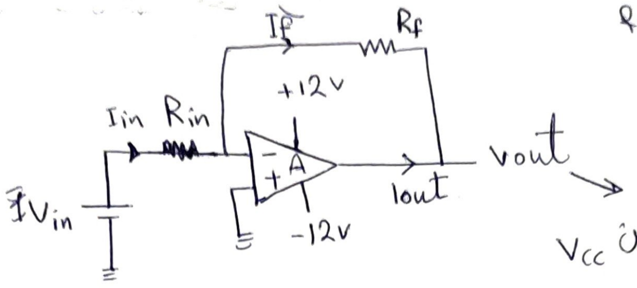
$V_1 = V_2$



Ro

Close loop Gain

هو مقدار $\frac{V_o}{V_s}$ بوجود FB
Feed Back



لازم ما تكون أكبر من V_{cc}

* inverting op- Amp

$V_d = V_2 - V_1$

$V_{out} = A . V_d \Rightarrow A . (V_2 - V_1)$

قانون المضخم العاكس =

$V_{out} = \frac{-R_f}{R_{in}} \times V_{in}$

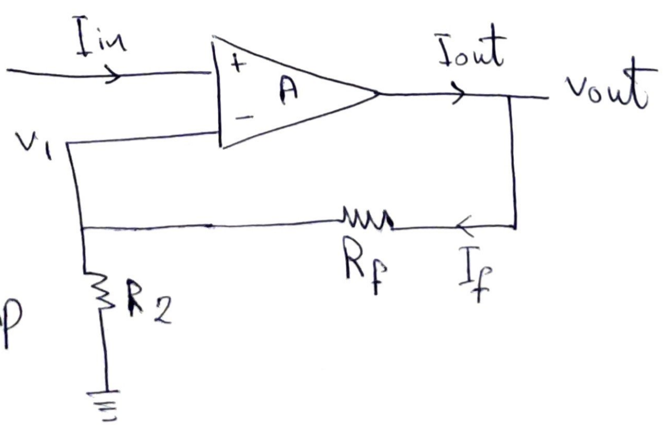
$Gain\,(A_v) = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$

$R_f \Rightarrow$ هي المقاومة بين طرفين Inverting و Vout

$R_{in} \Rightarrow$ هي المقاومة بين طرفين Inverting والإشارة الداخلة Vin

Gain (Av): هو معامل تكبير الإشارة ويدل على عدد مرات تكبير إشارة الدخل

Vin



*non Inverting Amp

$$A_{(v)} = 1 + \frac{R_f}{R_2}$$

$$V_1 = \frac{R_2}{R_2 + R_f} \times V_{out}$$

Ideal Summing point : $V_1 = V_{in}$

Voltage Gain $A_{(v)}$ is equal to : $\frac{V_{out}}{V_{in}}$

Then : $A_{(v)} = \frac{V_{out}}{V_{in}} = \frac{R_2 + R_f}{R_2}$

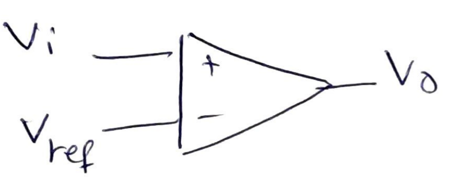
$$A_{(v)} = \frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_2}$$

$A \geq 1$

Comparator Amp مكبر مقارن

الهدف منه مقارنة جهدين عند المدخلين وانتاج اشارة تدل على الجهد الاكبر

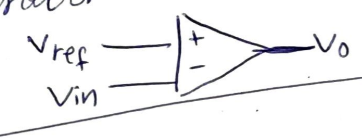
1) Non inv. Comparator



$V_i > V_{ref}$ V_o = Logic 1

$V_i < V_{ref}$ V_o = logic 0

2) inv. Comparator

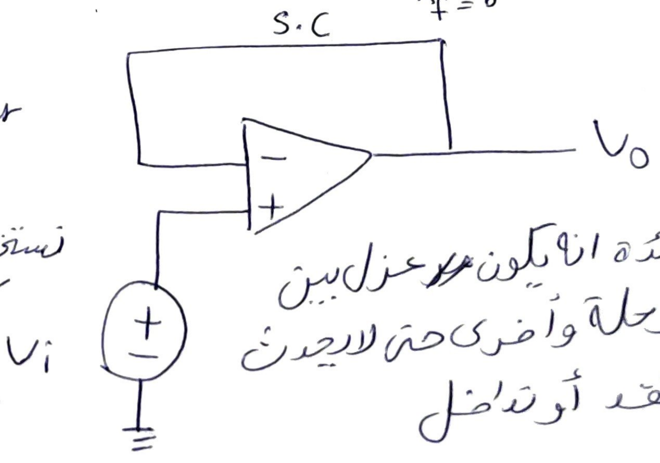


$V_i > V_{ref} \Rightarrow V_o = 0$

$V_{in} < V_{ref} \Rightarrow V_o = 1$

Voltage follower

Buffer



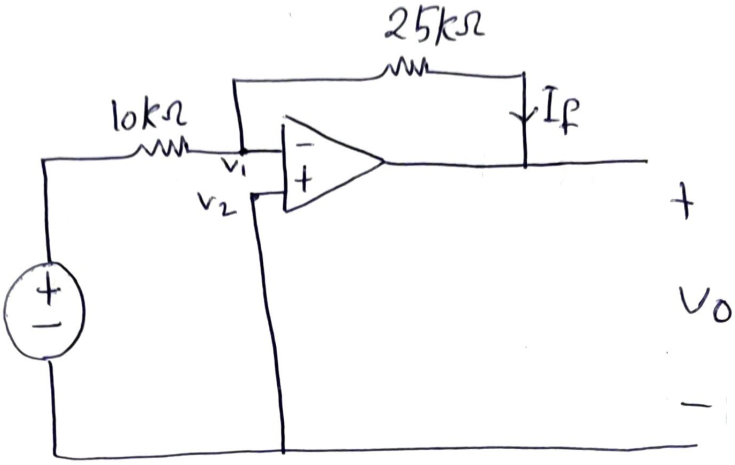
$V_o = V_{in}$

نستخدم هذا النوع لما يكون عندنا أكثر من مرحلة تكبير نخليه في الوسط حتى لا يحدث تداخل

فائدته انه يكون عازل بين مرحلة وأخرى حتى لا يحدث فقد أو تداخل

Ex :-

Inverting op_amp

1) 

For $V_i = 0.5V$ find :- 1) V_o
2) I_f

∵ inverting op amp

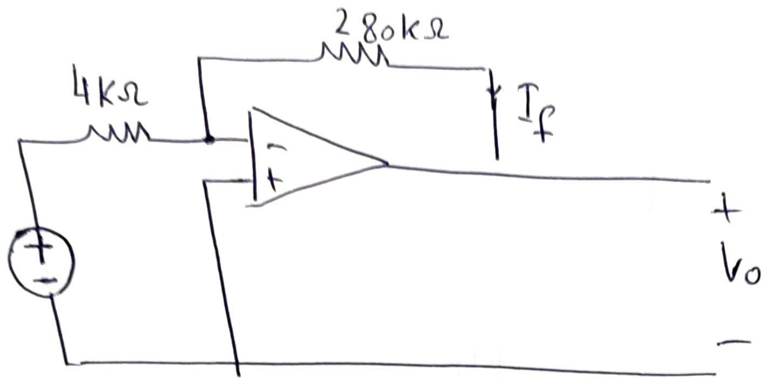
1) $$\therefore V_{out} = \frac{-R_f}{R_{in}} \times V_{in}$$

$$= \frac{-25k}{10k} \times 0.5V = -1.25 \text{ volt}$$

2) $$I_f = \frac{V_1 - V_o}{R_f} \Rightarrow V_1 = 0$$

$$I_f = \frac{0 - (-1.25)}{25k\Omega} = 0.05mA$$

2)



Ideal op-amp
inverting op-Amp

$$\frac{V_o}{V_i} = \frac{-R_f}{R_{in}}$$

find $\frac{V_o}{V_i}$, V_o, and i_f

Gain :- $\frac{V_o}{V_i} = -\frac{280}{4} = -70$

$$V_o = \frac{-R_f}{R_{in}} \cdot V_i$$

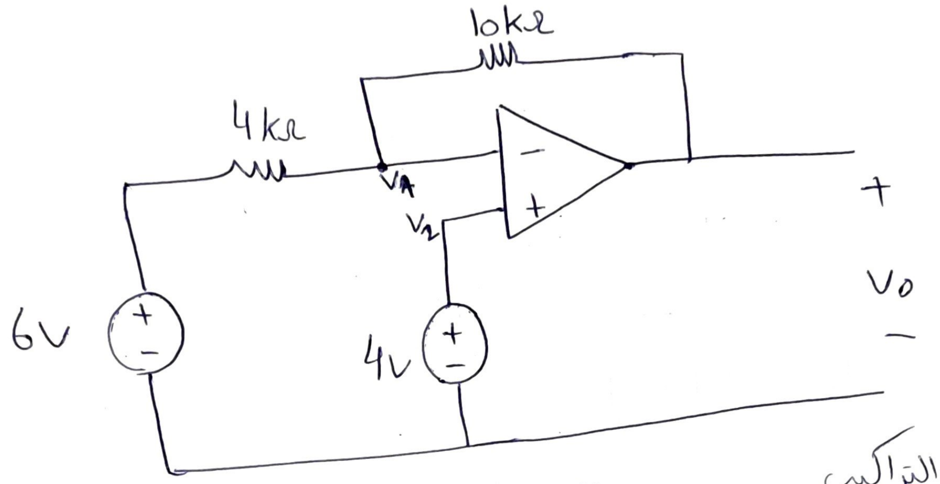
$$= -70 \times 45mV = -3.15 \text{ Volt}$$

$$i_f = \frac{V_1 - V_o}{R_f} = \frac{0 - (-3.15)}{280k\Omega} =$$ ~~26.25 μA~~ 11.25 μA

* Non-inverting op-amp

Ex

find : V_o

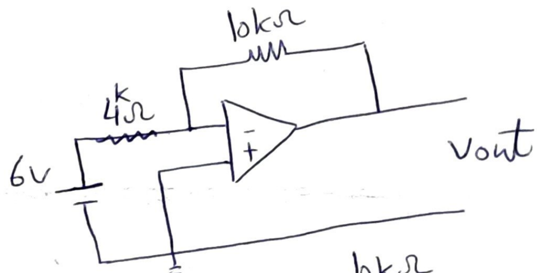


by using superposition theorem :- باستخدام نظرية التراكيب

A $V_o = V_{o1} + V_{o2}$

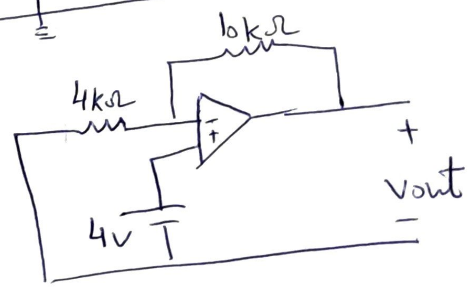
6V effect $\therefore V_o = -\frac{10}{4} \times 6$

$V_{o1} = -15V$



4V effect $\therefore V_{o2} = (1 + \frac{10}{4}) * 4$

$= 14V$



$\therefore V_o = -15 + 14 = -1V$

OR by using KCL : $\frac{6 - V_1}{4k\Omega} = \frac{V_1 - V_o}{10k\Omega}$

$\because V_1 = V_2 = 4$

$\frac{6 - 4}{4k\Omega} = \frac{4 - V_o}{10k\Omega}$

$\therefore V_o = -1V$

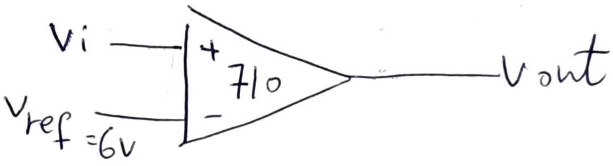
~~Ex: Find Vo~~ ① for

Comparator → { 741, 351 } → logic 1 = $+V_{cc}$, logic 0 = $-V_{cc}$

② 710 ⇒ logic 1 = 3.2V

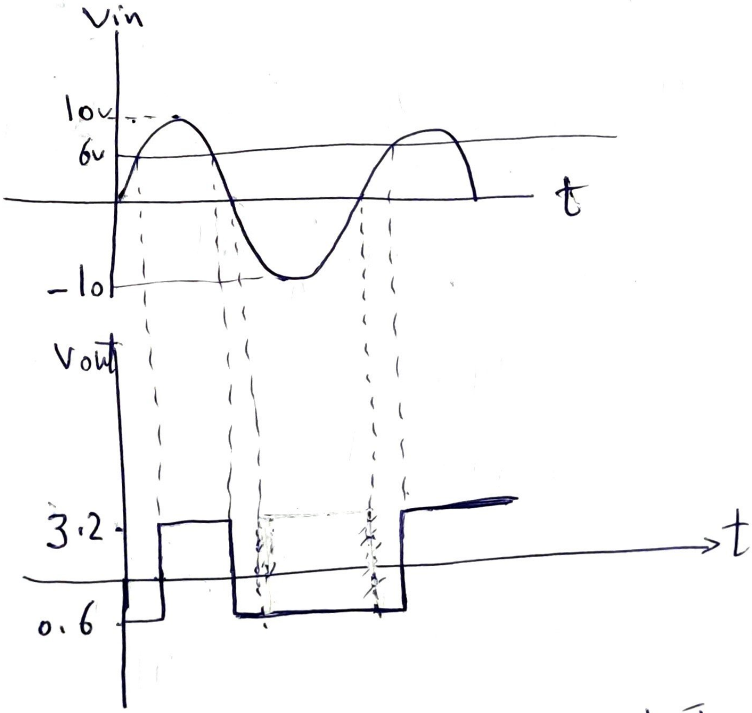
logic 0 = −0.6V

Ex:- find Vout assuming 710 comparator if $V(t) = 10 \sin \omega t$



if $V_i > V_{ref} \Rightarrow V_{out} = 3.2V$

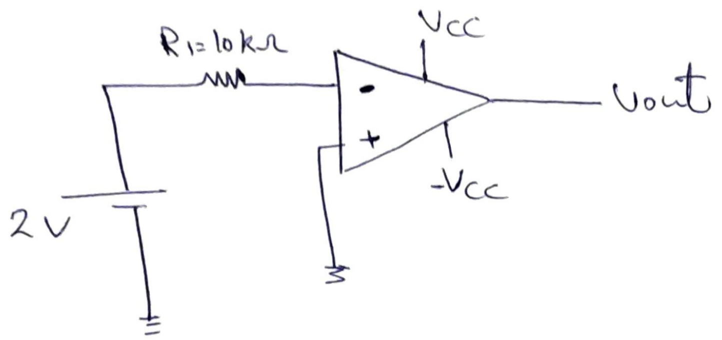
$V_i < V_{ref} \Rightarrow V_{out} = -0.6$



تحولت اشارة الإدخال من موجة جيبية إلى بلس

١, ٥

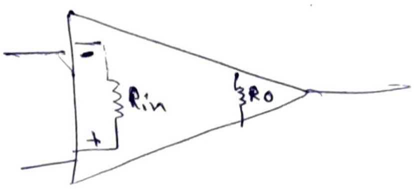
open loop gain and Close loop gain



1) find Vo when $A = 2\times10^5$

$R_{in} = 2M\Omega$

$R_o = 50\Omega$



$V_o = A_{OL} V_{in}$

$= (2\times10^5)(2) = 400000V$ (saturated) $V_o = V_{CC}$

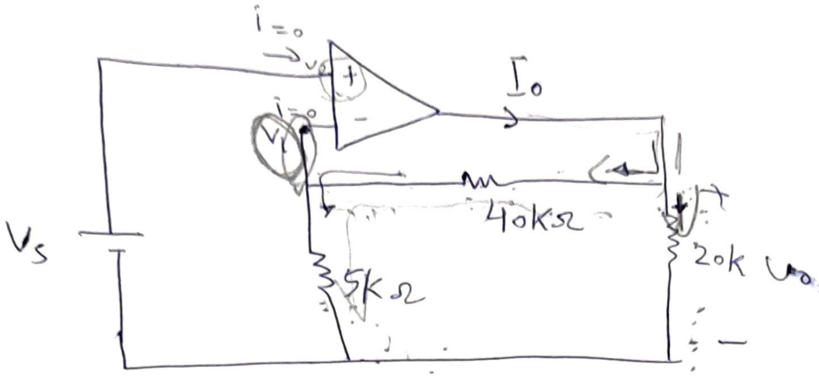
2) Close loop gain when $R_f = 20k\Omega$

$$A_{CL} = \frac{-R_f}{R_{in}} = \frac{-20k\Omega}{10k\Omega} = -2$$

$V_o = -2(2V) = -4V$

#

Ex :- find $\frac{V_o}{V_s}$ (A) and i_o when $V_s = 1$ volt



∴ بما أن لم يحدد بارامترات ∴ نعتبره مثالي ونحل

في المثالي

$i_1 = 0$

$i_2 = 0$

$V_1 = V_2 = V_s$ — 1

VDR $\quad V_1 = \frac{V_o \times 5}{5+40}$

$V_s = V_o \frac{5}{45} \Rightarrow \frac{V_o}{V_s} = 9 = \frac{9}{1}$:- Close loop voltage gain

$V_s \, 45 = V_o \, 5$

عندما $V_s = 1$

$V_o = 9\,V$

$i_o = \frac{V_o}{(5+40)k} + \frac{V_o}{20}$

$i_o = \frac{9}{45k} + \frac{9}{20k} = 0.657\,mA$

Ex:-

Design an op-amp circuit that will produce the output

$$V_o = \sin\omega t \quad , \quad V_{in} = 2\sin\omega t$$

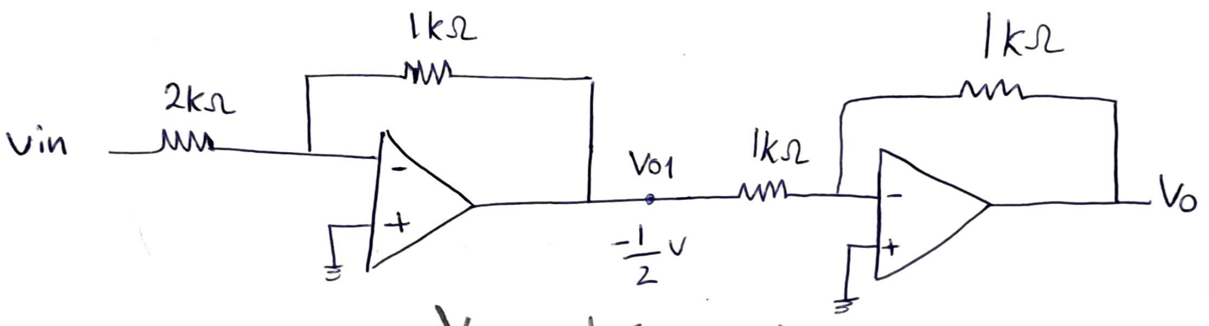
Solution :-

$$A = \frac{V_o}{V_{in}} = \frac{\sin\omega t}{2\sin\omega t} = \frac{1}{2}$$

$$A = \frac{-R_f}{R_{in}} = \frac{1}{2}$$

$$R_{in} = 2R_f$$

let $R_f = 1k$ ∴ $R_{in} = 2k$



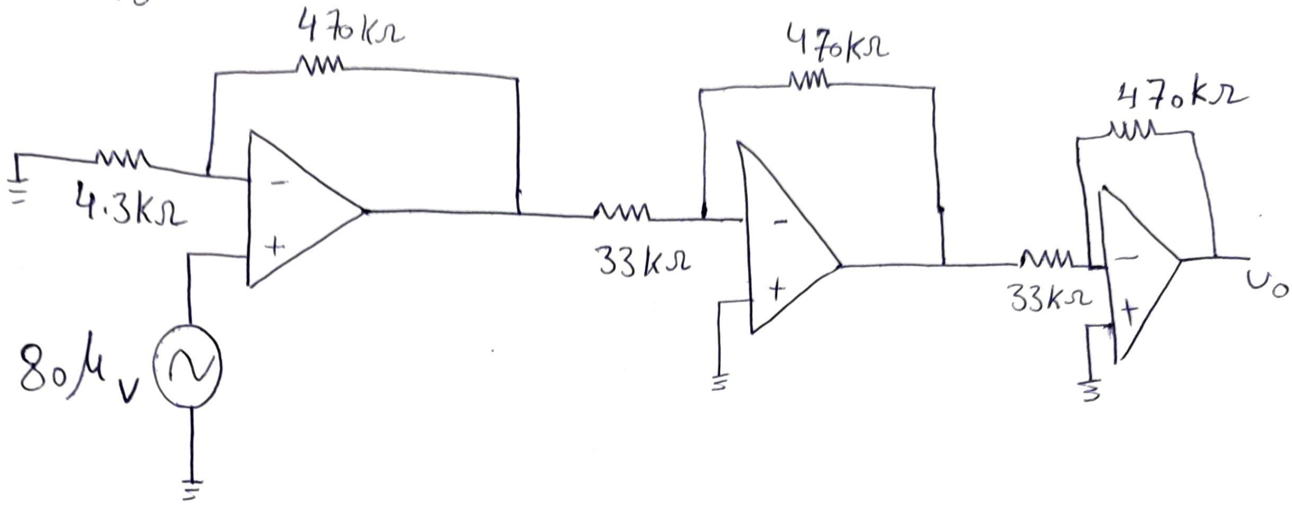
$$V_{o1} = \frac{-1}{2}(2\sin\omega t)$$

$$V_o = A \cdot V_{in}$$

$$= \frac{-1k\Omega}{1k\Omega}(-\sin\omega t) = \sin\omega t$$

$$\therefore V_o = \sin\omega t$$

Ex:-



calculate the output voltage

Solution:-

The amplifier gain is :

$$A = A_1 A_2 A_3$$

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

$$= \left(1 + \frac{470k\Omega}{4.3\,k\Omega}\right)\left(-\frac{470k\Omega}{33\,k\Omega}\right)\left(\frac{-470\,k\Omega}{33k\Omega}\right)$$

$$= 22 \times 10^3$$

$$V_o = A V_i$$

$$= 22 \times 10^3 \,(80\,\mu v) = 1.78V$$

Ex:- find v ... and i

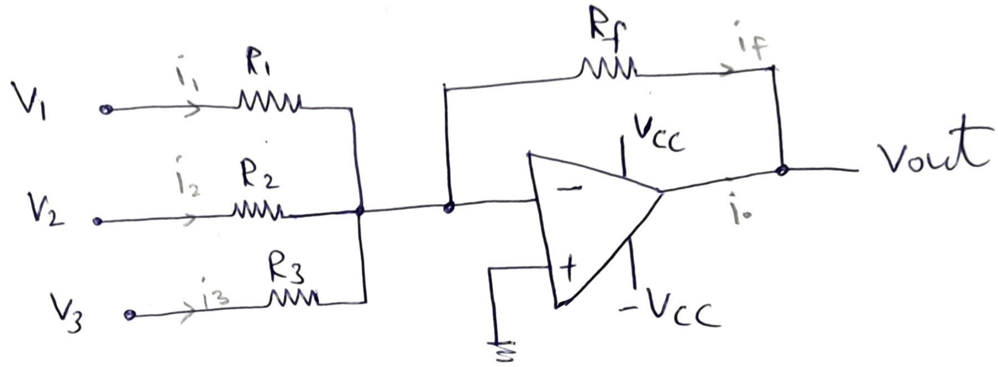
19/1/2022

الأربعاء - م تحكم

الثلاثاء اتصالات ١١:٣٠ 25/1/2022

Summing Amplifier:- "المكبر الجامع"

يقوم بجمع الجهود الموجودة عند الدخل



by using superposition theorem

$$\therefore V_{out} = A_{CLV1} \cdot V_1 + A_{CLV2} \cdot V_2 + A_{CLV3} \cdot V_3$$

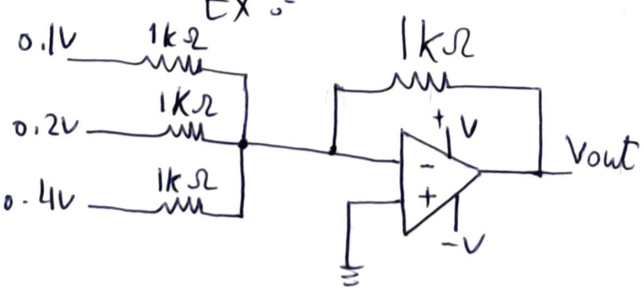
$$A_{CLV_1} = \frac{-R_f}{R_1}, \quad A_{CLV_2} = \frac{-R_f}{R_2}, \quad A_{CLV_3} = \frac{-R_f}{R_3}$$

$$\therefore V_{out} = \frac{-R_f}{R_1}(V_1) + \frac{-R_f}{R_2}(V_2) + \frac{-R_f}{R_3}(V_3)$$

$$* \quad V_{out} = -\left(\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2 + \frac{R_f}{R_3} V_3\right)$$

$V_{out} = -(V_1 + V_2 + V_3) \quad \therefore \Leftarrow R_1 = R_2 = R_3 = R_f$ في حالة

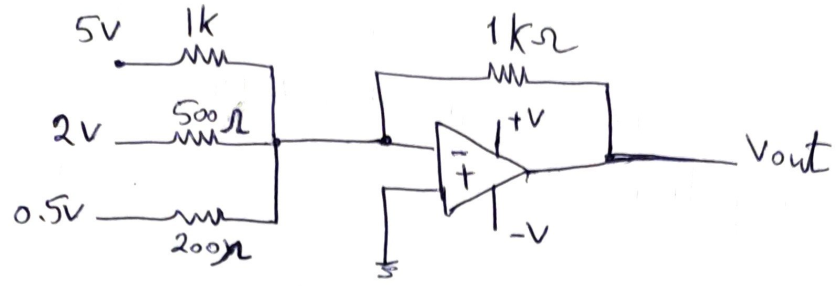
Ex:-



find Vout

$$\Rightarrow V_{out} = -(V_1 + V_2 + V_3)$$
$$= -(0.1 + 0.2 + 0.4)$$
$$= -0.7V$$

Ex:-



Find Vout

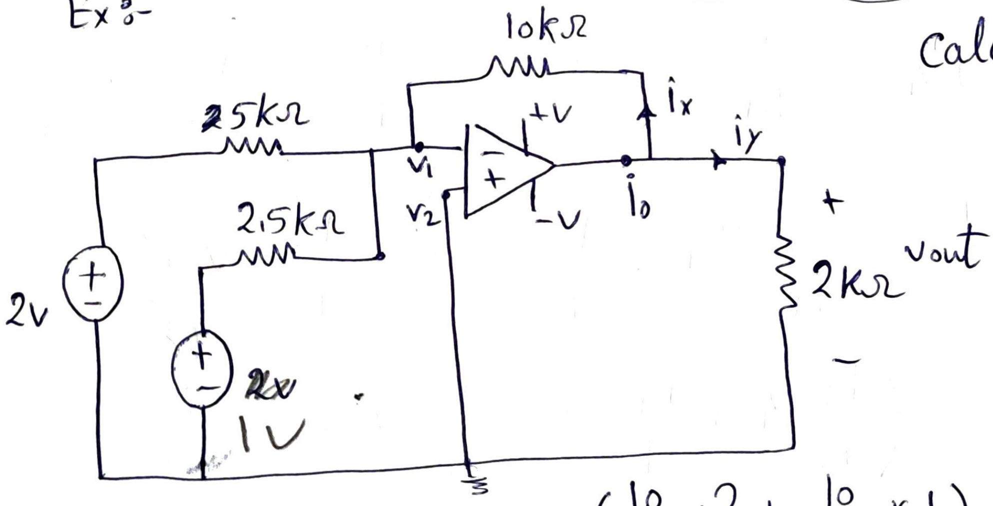
$$V_{out} = -\left(\frac{R_f}{R_1} \cdot V_1 + \frac{R_f}{R_2} \cdot V_2 + \frac{R_f}{R_3} V_3\right)$$

$$= -\left(\frac{1k}{1k} \times 5 + \frac{1k}{500} \times 2 + \frac{1k}{200} \times 0.5\right)$$

$$= -(5^v + 4v + 2.5v) = -11.5\,V$$

Ex:-

Calculate v_o & i_o in the op-Amp Circuit

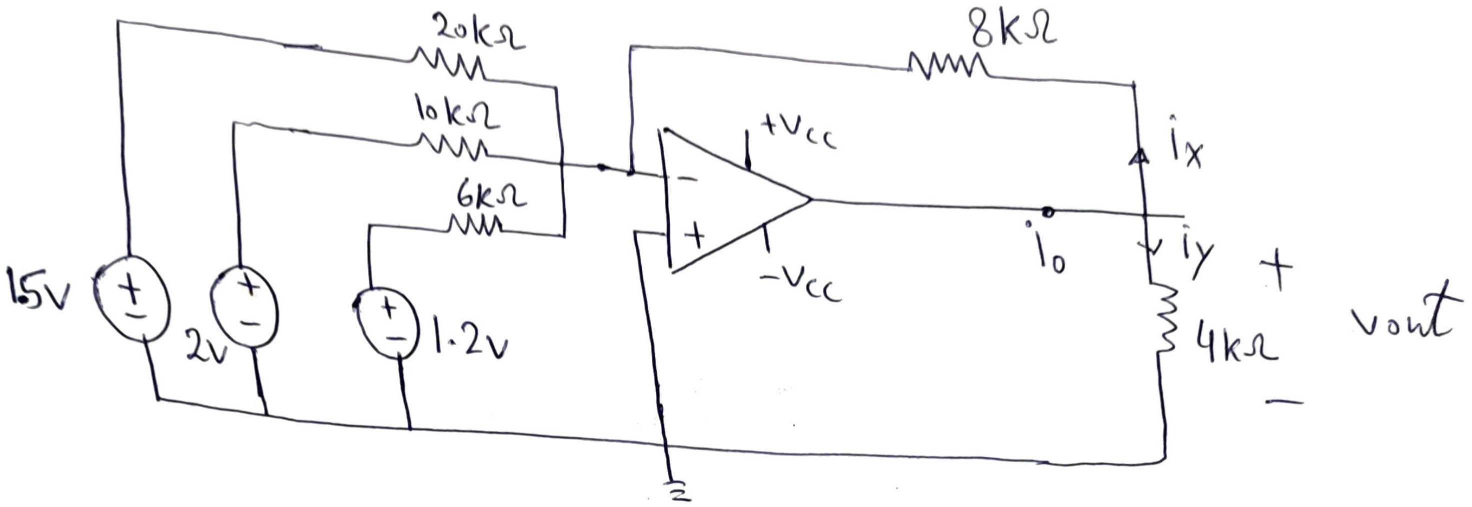


$$V_o = -\left(\frac{10}{5} \times 2 + \frac{10}{2.5} \times 1\right) = -8\,\text{volt}$$

$$i_o = \frac{V_o - V_1}{R_f} + \frac{V_o - 0}{R_{2k\Omega}}$$

$$= \frac{-8}{10k} + \frac{-8}{2k} = -4.8\,mA$$

Ex :- find V_o and i_o



$$V_{out} = -\left(\frac{8k}{20k} \times 1.5 + \frac{8k}{10k} \times 2 + \frac{8k}{6k} \times 1.2\right)$$

$$= -3.8\ V$$

$$i_o = i_x + i_y$$

$$= \frac{V_o - 0}{8k\Omega} + \frac{V_o - 0}{4k\Omega}$$

$$= \frac{-3.8V}{8k\Omega} + \frac{-3.8V}{4k\Omega} = -1.425\ mA$$

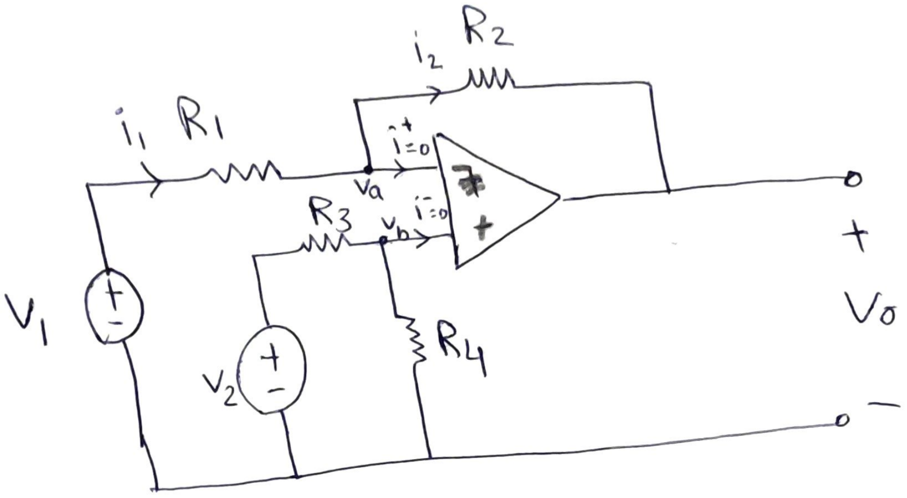
$$\frac{0 - V_o}{8k\Omega} + \frac{V_o - 0}{4k\Omega}$$

$$\frac{3.8}{8k\Omega} + \frac{-3.8}{4k\Omega} = 0.475 - 0.95 = -0.48$$

Subtraction op-Amp

المكبر الطارح

25/1/2022



$i^+ = i^- = 0$

$$i_1 = i_2 = \frac{V_1 - V_a}{R_1} = \frac{V_a - V_o}{R_2}$$

$R_1(V_a - V_o) = R_2(V_1 - V_a)$

$R_1 V_a - R_1 V_o = R_2 V_1 - R_2 V_a$

$R_2 V_1 - R_2 V_a - R_1 V_a = -R_1 V_o$

$-\frac{R_2 V_1}{R_1} + \frac{R_2 V_a}{R_1} + \frac{R_1 V_a}{R_1} = V_o$

$\left(1 + \frac{R_2}{R_1}\right) V_a - \frac{R_2}{R_1} V_1 = V_o$

$$\therefore V_o = \left(1 + \frac{R_2}{R_1}\right) V_a - \frac{R_2}{R_1} V_1$$

$\because V_a = V_b$ for ideal op-Amp

$$V_b = V_{4\Omega}$$

$$V_a = V_b = V_2 \cdot \frac{R_4}{R_3 + R_4}$$

$$* \quad \therefore V_o = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3 + R_4}\right) \cdot V_2 - \frac{R_2}{R_1} V_1$$

$$* \quad V_o = \frac{R_2(1 + R_1/R_2)}{R_1(1 + R_3/R_4)} \cdot V_2 - \frac{R_2}{R_1} V_1$$

if: $\frac{R_2}{R_1} = \frac{R_4}{R_3}$ or $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ $\therefore V_o = \frac{R_2}{R_1} \cdot V_2 - \frac{R_2}{R_1} \cdot V_1$

$$V_o = \frac{R_2}{R_1}(V_2 - V_1)$$

, $V_o = 0$ when $V_1 = V_2$

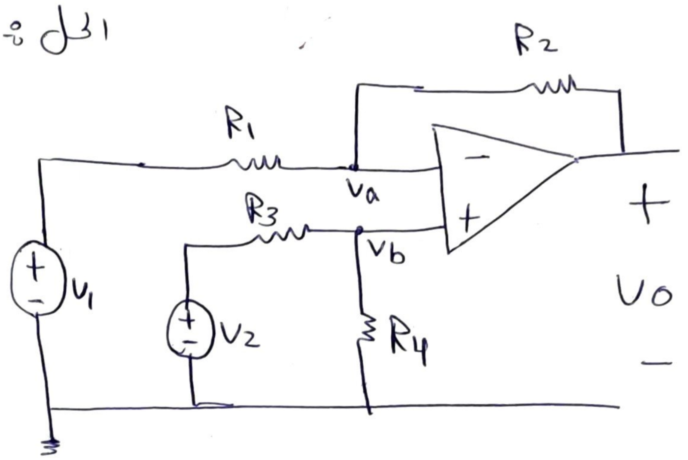
$R_2 = R_1 \quad \& \quad R_3 = R_4$

Gain = 1 & $V_o = V_2 - V_1$ في هذه الحالة لا يحدث تكبير

Ex: 1

Design an op-Amp Circuit with inputs V_1 & V_2 such that: $V_o = 3V_2 - 5V_1$

الحل: (١) تصميم باستخدام مكبر واحد



$$V_o = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3 + R_4}\right)V_2 - \frac{R_2}{R_1}V_1$$

$$\frac{R_2}{R_1} = 5 \quad \therefore R_2 = 5R_1$$

نفرض: $R_1 = 10k\Omega$

$\therefore R_2 = 50k\Omega$

$$\because \frac{R_2}{R_1} = 5 \qquad \therefore \left(1 + \frac{R_2}{R_1}\right) = 6$$

$$\therefore 6\left(\frac{R_4}{R_3 + R_4}\right) = 3 \qquad \frac{6}{3}R_4 = \frac{3}{3}R_3 + R_4$$

$$2R_4 = R_3 + R_4 \quad \Rightarrow R_4 = R_3$$

$2R_4 - R_4 = R_3 \Rightarrow R_4 = R_3$

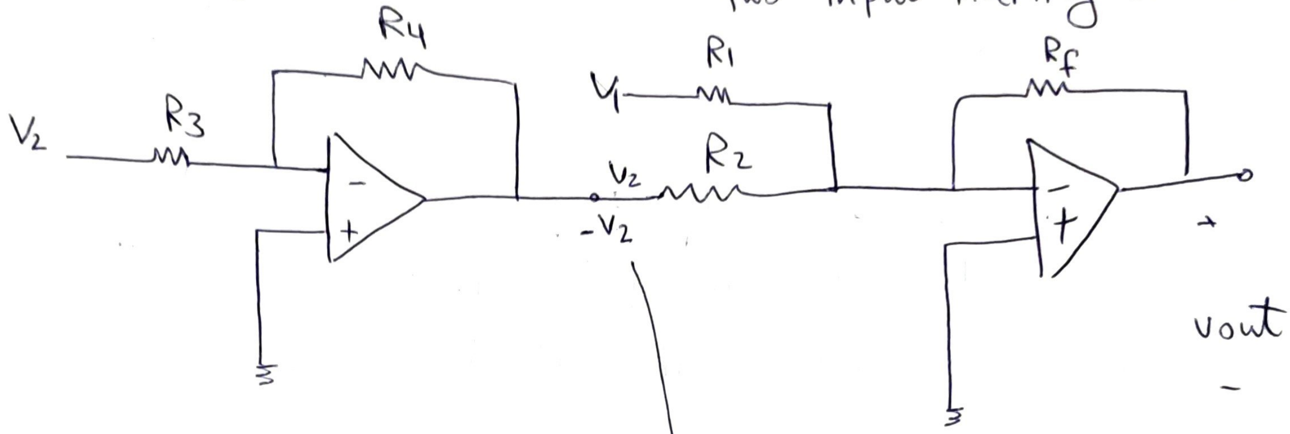
نفرض أن $R_3 = 10k$

$\therefore R_4 = 10k$

الحل بطريقة أخرى

الحل باستخدام نوعين من الكبرات

inverting amp — two input inverting summer



$R_4 = R_3 = 10\,k\Omega$

$R_f = 15\,k\Omega$

$R_1 = 3\,k\Omega$

$R_2 = 5\,k\Omega$

1) $V_{out} = \frac{-10\,k}{10\,k} \cdot V_2$

$V_{out} = -V_2$

2) $V_{out} = -\frac{R_f}{R_2} \cdot (V_2) + \left(-\frac{R_f}{R_1}\right) V_1$

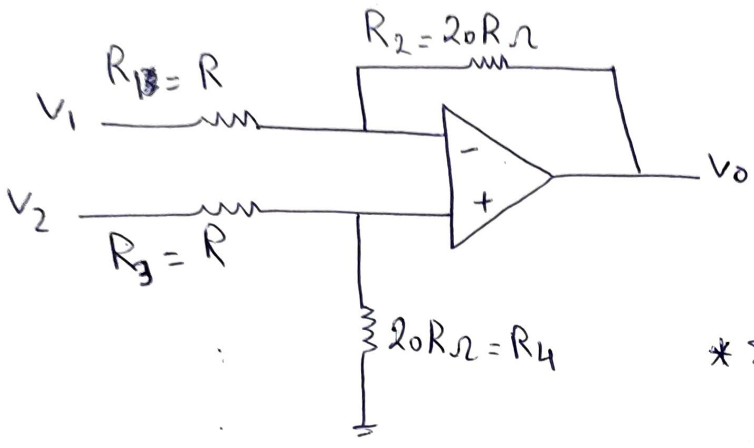
$= -\frac{15\,k\Omega}{5\,k\Omega}(-V_2) - \frac{15\,k\Omega}{3\,k\Omega} V_1$

$= 3V_2 - 5V_1$

Ex :-

Find V_o if $V_{in_1} = 10 \sin(2\pi 60 t) - 0.1 \sin(2\pi 1000 t)$

$V_{i2} = 10 \sin(2\pi 60 t) + 0.1 \sin(2\pi 1000 t)$



* subtraction op amp

$\because \frac{R_1}{R_2} = \frac{R_3}{R_4}$

$\therefore V_o = \frac{R_2}{R_1}(V_2 - V_1)$

$= \frac{20 R\Omega}{R\Omega}\left(10 \sin(2\pi 60 t) + 0.1 \sin(2\pi 1000 t) - 10 \sin(2\pi 60 t) + 0.1 \sin(2\pi 1000 t)\right)$

$20(0.2 \sin(2\pi 1000 t)) = 4 \sin(2\pi 1000 t)$

Ex: 2

Design a difference amp with gain 5.

$V_o = 5(V_2 - V_1)$

if $R_1 = R_3$ ، $R_2 = R_4$ ⇐ عملياً لازم

$$V_o = \frac{R_2}{R_1}(V_2 - V_1)$$

$\therefore \frac{R_2}{R_1} = 5$ $\therefore R_2 = 5R_1$

نفرض

$R_1 = 10k\Omega$

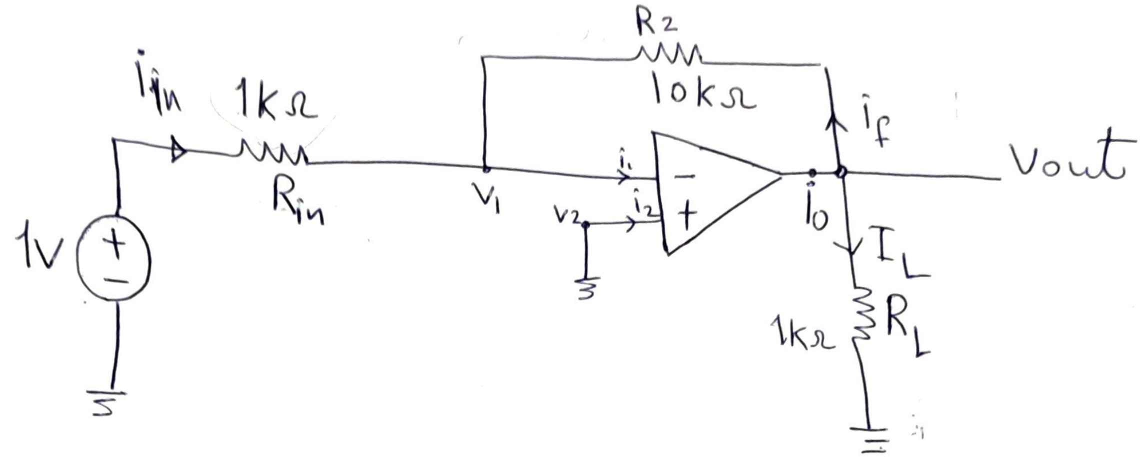
$\therefore R_2 = 50k\Omega$

$R_3 = 10k\Omega$

$\therefore R_4 = 50k\Omega$

فى الدائرة مكبر العمليات المبينة فى الشكل التالى أوجد :

V_o ، i_{in} ، i_o ، i_L ، (الكسب فى الجهد والتيار والقدرة)



∵ Ideal op - Amp ∴ $i_1 = i_2 = 0$

$V_1 = V_2 = 0$ ⏚

✳ $i_{in} = \dfrac{V_S - V_1}{R_{in}} = \dfrac{1v - 0}{1k\Omega} = 1mA$

✳ $i_{in} = i_f = 1mA$

✳ $V_{out} = \dfrac{-R_f}{R_{in}} \cdot V_{in} = \dfrac{-10k}{1k}(1v) = -10v$

✳ $i_L = \dfrac{V_o}{R_L} = \dfrac{-10v}{1k\Omega} = -10mA$

$i_o = i_f + i_L$

$= 1m + 10m$

$= 11mA$

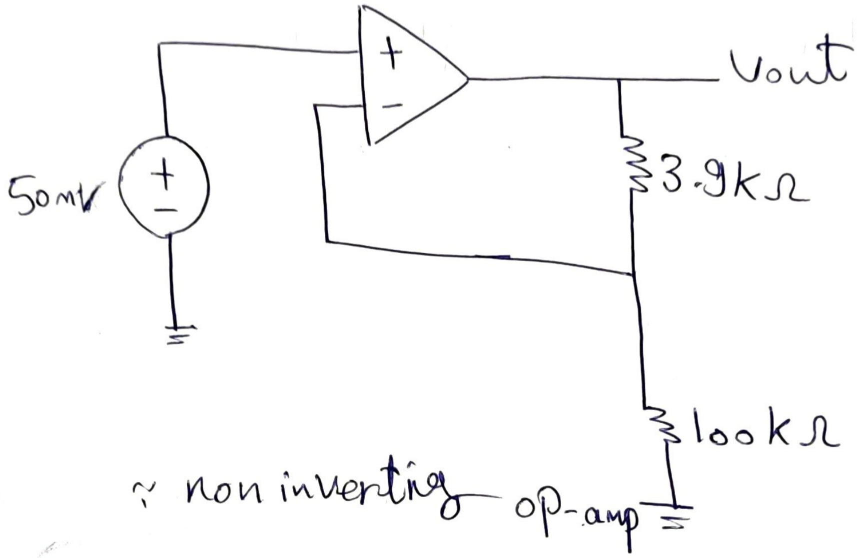
$A_V = \dfrac{V_o}{V_i} = \dfrac{-10v}{1v} = -10$

$A_I = \dfrac{i_o}{i_{in}} = \dfrac{-10mA}{1mA} = -10$

$A_P = \dfrac{P_L}{P_i} = \dfrac{(-10v)(-10mA)}{(1v)(1mA)} = 100$

Ex:-

Find A_{CL} , V_{out}



∴ non inverting op-amp

$$\therefore A_{CL} = \frac{R_f}{R_1} + 1$$

$$= \frac{3.9\,k\Omega}{100\,k\Omega} + 1$$

$$= 1.039$$

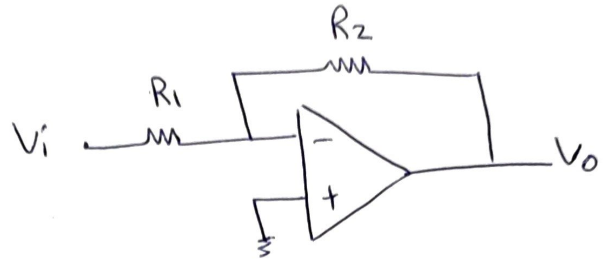
$$V_{out} = A_{CL} \cdot V_{in}$$

$$= 1.039\,(50\,mV)$$

$$= 52\,mV$$

Ex :-

gain = 26 dB



use resistors no larger than 1 MΩ Design the Circuit having the largest possiible input resister.

Solution:-

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

$$26\ dB = 20 \log\left(\frac{-R_2}{R_1}\right)$$

$$\log\left(\frac{-R_2}{R_1}\right) = \frac{26}{20} = 1.3$$

$$\frac{-R_2}{R_1} = 10^{(1.3)} \Rightarrow \log^{-1}$$

$$\frac{-R_2}{R_1} = 19.95$$

$$\frac{-R_2}{R_1} \simeq 20$$

$\therefore R_2 = 20 R_1$ let $R_2 = 1M\Omega$

$$1M\Omega = 20 R_1$$

$$\therefore R_1 = \frac{1M}{20} = \frac{1000\,k}{20} = 50k\Omega$$

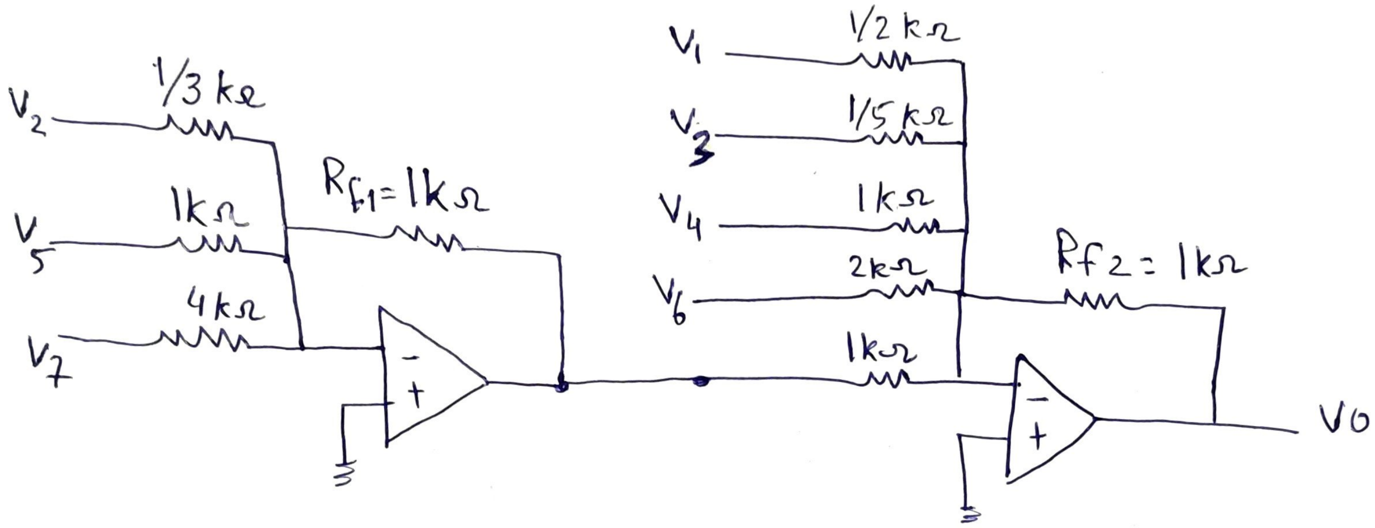
$\therefore R_2 = 1M\Omega$, $R_1 = 50k\Omega$

Ex:-

Design an op amp circuit that will produce the output $\Rightarrow V_o = -2V_1 + 3V_2 - 5V_3 - V_4 + V_5 - 0.. V_6 + \frac{1}{4} V_7$

b) Draw the output if $V_1 = 1V$, $V_2 = \sin\omega t (v)$, $V_3 = 0.2V$, $V_4 = 2\sin\omega t (v)$, $V_5 = -2V$, $V_6 = -4V$ and $V_7 = 4V$

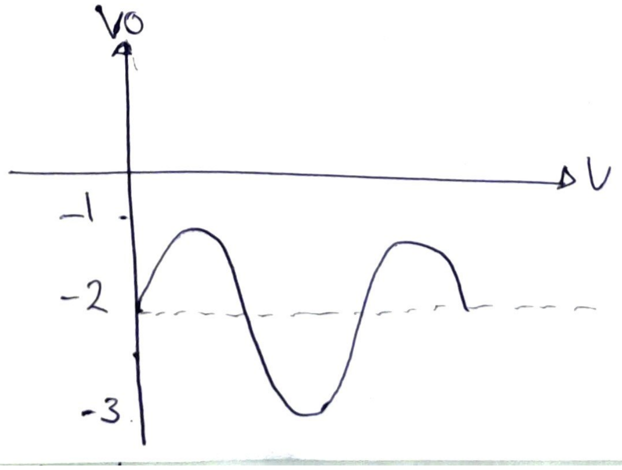
Sol:-



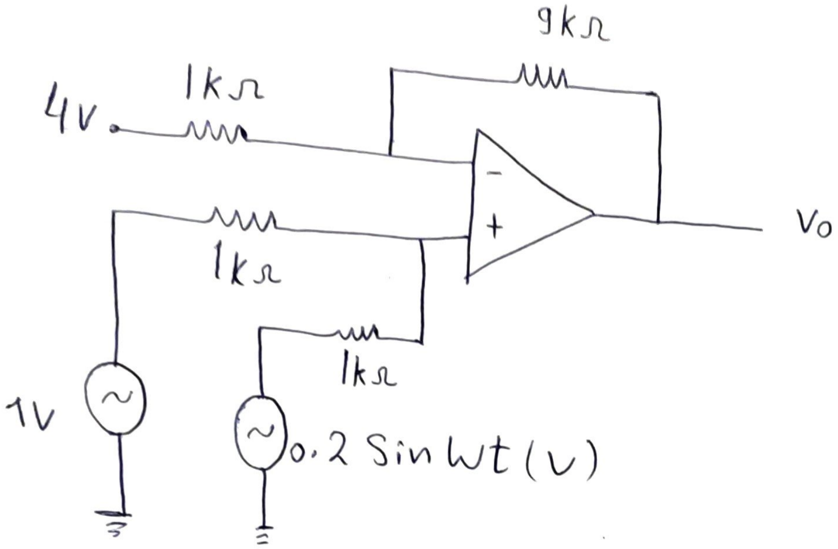
b) $V_o = -2(1) + 3(\sin\omega t) - 5(0.2) - (2\sin\omega t) + (-2) - 0.5(4) + 0.25(4)$

$= -2 + 3\sin\omega t - 1 - 2\sin\omega t - 2 + 2 + 1$

$\therefore V_o = \sin\omega t - 2$

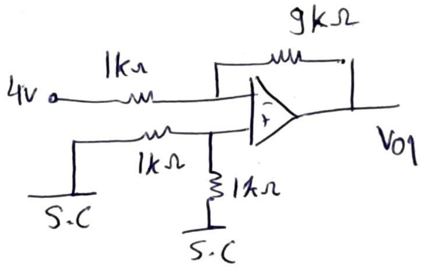


find $V_o(t)$



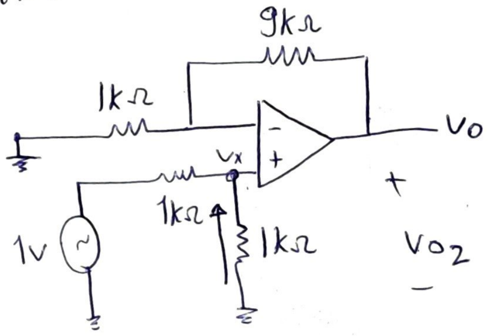
by using superposition

[A] for inverting mode ⇒ 4v active



$$V_{o_1} = \frac{-9k\Omega}{1k\Omega}(4v) = -36\text{ V}$$

[B] for non inverting mode ⇒ 1) 1v active



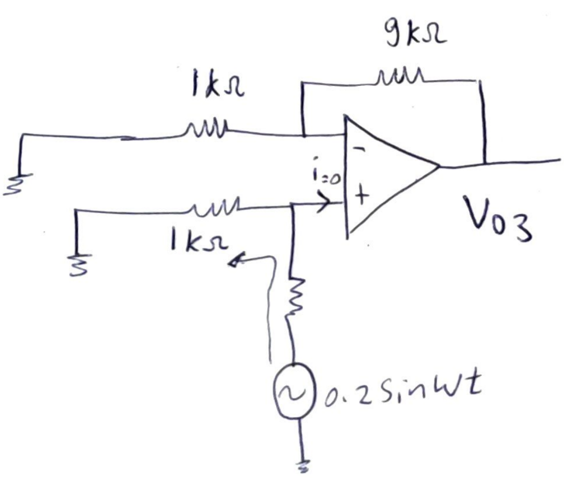
$$V_{o_2} = \left(1 + \frac{9k}{1k}\right)(V_x)$$

$$= 10\,V_x \quad \text{VDR}$$

$$= 10\left(1v \times \frac{1\Omega}{(1+1)\Omega}\right)v$$

$$= 5\text{ V}$$

2) 0.2 Sin wt active



$$V_{o_3} = \left(1 + \frac{9k\Omega}{1k\Omega}\right)\cdot V_y$$

$$V_{o_3} = 10\,V_y \Rightarrow V_y = V_i \cdot \frac{1}{1+1} = \frac{1}{2}V_i$$

$$V_{o_3} = 10\left(\frac{1}{2} \times 0.2\,\text{Sin}\,wt\right) = \text{Sin}\,wt$$

$\therefore V_o = V_{o1} + V_{o2} + V_{o3}$

$= -36 + 5 + \sin \omega t$

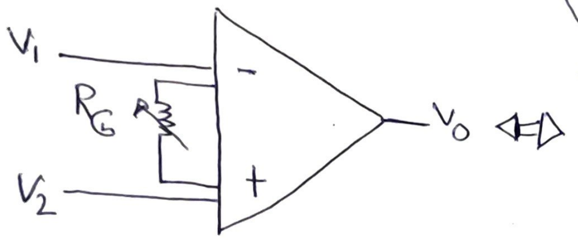
$V_o = -31 + \sin \omega t$

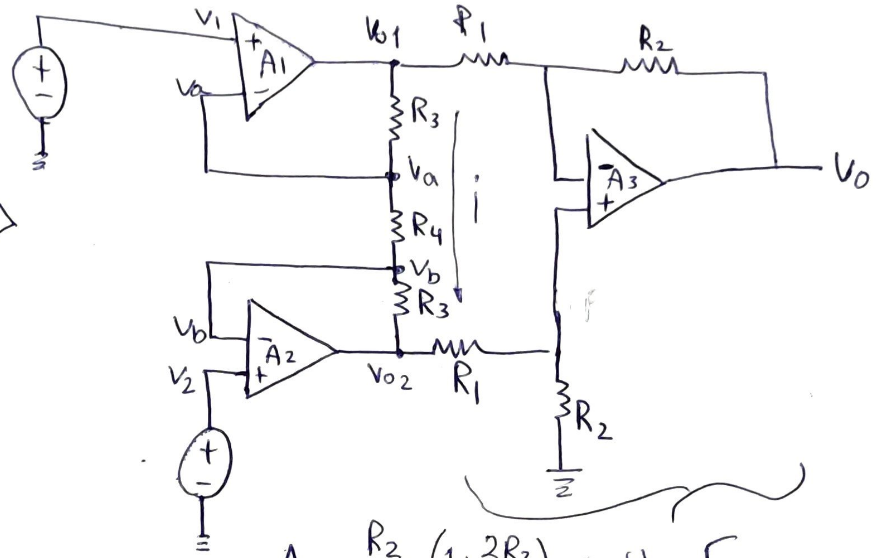
-2/2022

* Instrumentation Amplifier (IA) operational :-

(IA) is an amp. of low level signal used in Process control measurement applications system

يستخدم صناعيا بكثرة وهو موجود قطعة جاهزة ونستطيع تصميمه باستخدام 3 مكبرات





$$A_V = 1 + \frac{2R}{R_G}$$

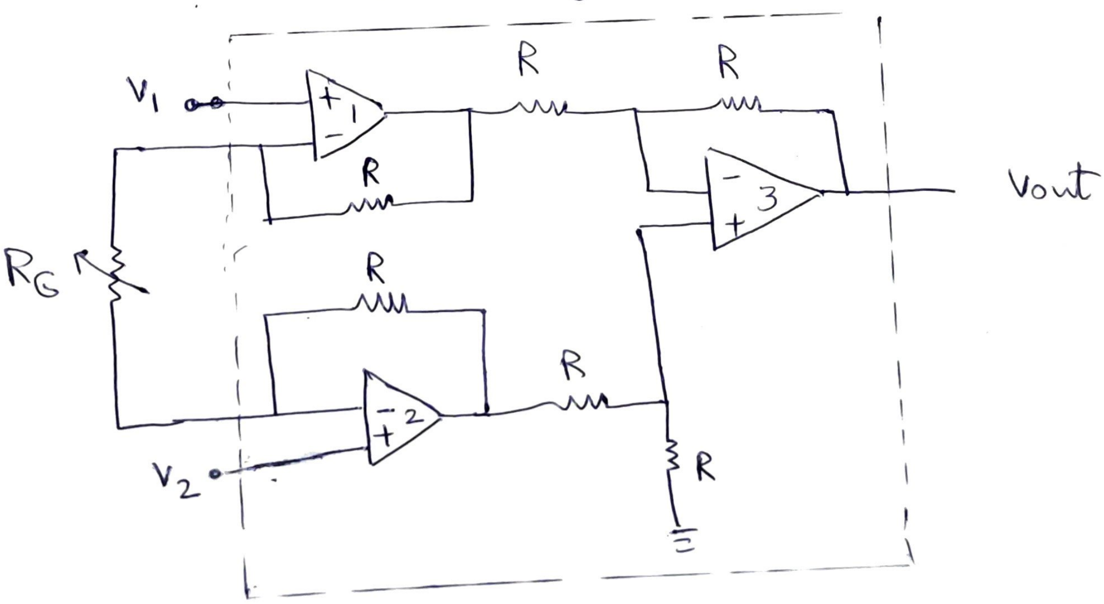
$$V_o = A_V (V_2 - V_1)$$

مكبر طارح ،

$$A_V = \frac{R_2}{R_1}\left(1 + \frac{2R_3}{R_4}\right)$$

$$V_o = \frac{R_2}{R_1}\left(1 + \frac{2R_3}{R_4}\right)(V_2 - V_1)$$

R_G : مقاومة متغيرة بين طرفين ضبط الكسب مقاومة ضبط الكسب
external gain setting resistor



* The Gain can be varied from 1 to 1000 by an external resistor whose value may vary from 100 to 10kΩ

* إستنتاج قانون (IA)

$$V_o = \frac{R_2}{R_1}(V_{o2} - V_{o1})$$

$$V_{o1} - V_{o2} = i(R_3 + R_4 + R_3)$$

$$= i(2R_3 + R_4)$$

$$\Rightarrow i = \frac{V_a - V_b}{R_4} \qquad V_a = V_1 \text{ ، } V_b = V_2$$

$$\therefore i = \frac{V_1 - V_2}{R_4}$$

$$V_{o1} - V_{o2} = \left(\frac{V_1 - V_2}{R_4}\right)(2R_3 + R_4)$$

$$V_{o1} - V_{o2} = \left(\frac{2R_3}{R_4} + 1\right)(V_1 - V_2)$$

محتاجين ل $V_{o2} - V_{o1}$ ⇐ نضرب في (-1)

$$-V_{o1} + V_{o2} = \frac{2R_3}{R_4} + 1(-V_1 + V_2)$$

$$\therefore V_{o2} - V_{o1} = \frac{2R_3}{R_4} + 1(V_2 - V_1)$$

$$\therefore V_o = \frac{R_2}{R_1}\left(\frac{2R_3}{R_4} + 1\right)(V_2 - V_1)$$

Ex:- 1

let $R = 10k\Omega$, $V_1 = 2.011V$ and $V_2 = 2.017V$
if R_G is adjusted to $500\ \Omega$ determine:-
1) the voltage gain
2) the output voltage

Solution:

1) $A_V = 1 + \frac{2R}{R_G} = 1 + \frac{2 \times 10.000}{500} = 41$

2) $V_o = A_V (V_2 - V_1)$

$= 41(2.017 - 2.011) = 41(6) mV = 246 mV$

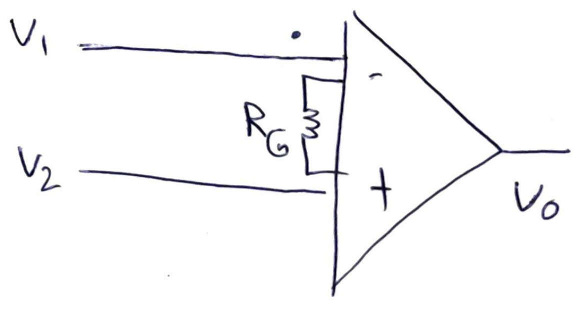
Ex:- 2

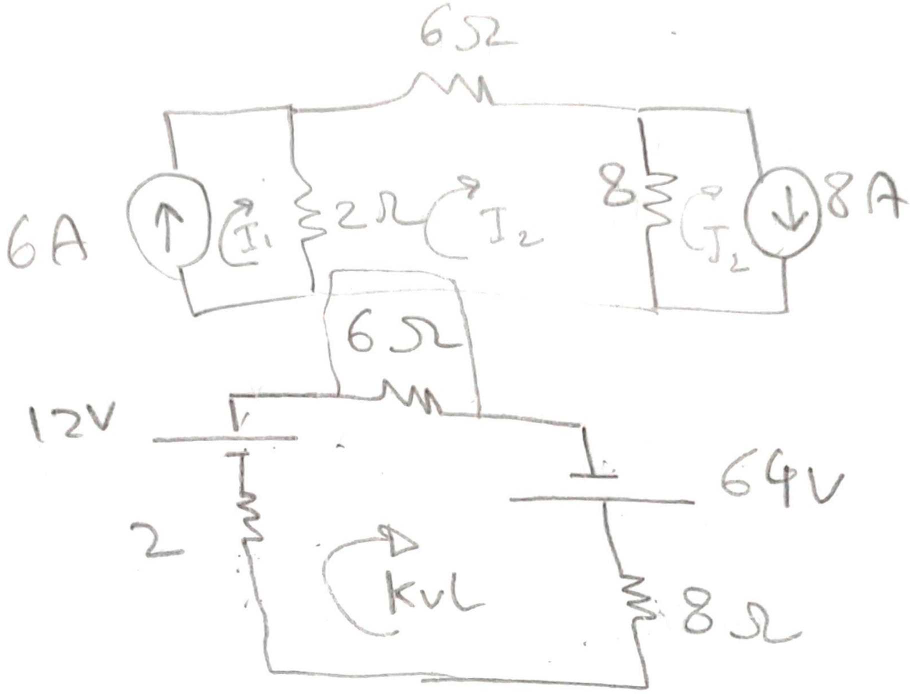
Determin the value of the R_G required for the IA in fig to produce a gain of 142 when $R = 25k\Omega$

$A_V = \left(1 + \frac{2R}{R_G}\right)$

$142 = \left(1 + \frac{2 \times 25000}{R_G}\right)$

$R_G = 354.6\Omega$





$-2I + 12 - 6I_2 + 64 - 8I_2 = 0$

$-16I = -76$

$I = \frac{-76}{-16} = +$

Roaa Aburageba.

aburagebaroaa@gmail.com

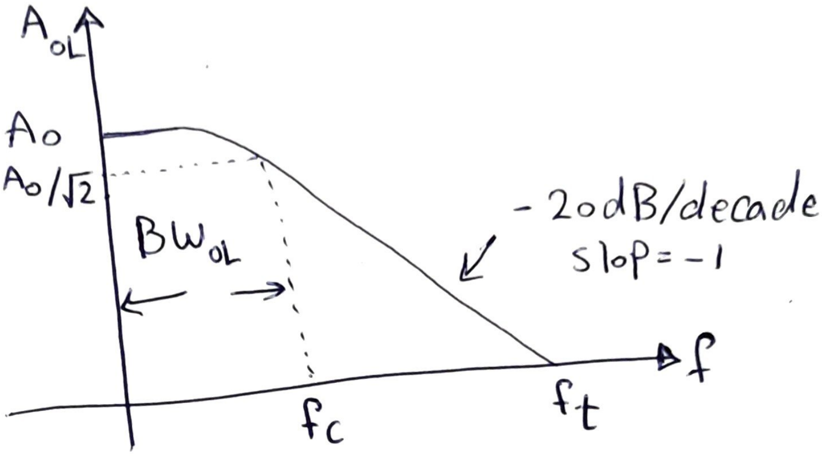
* Practical op-amp

1) Frequency Response

is the ralation between freq- and gain.

*open loop :-

$f_t = A_{OL}(f_c)$

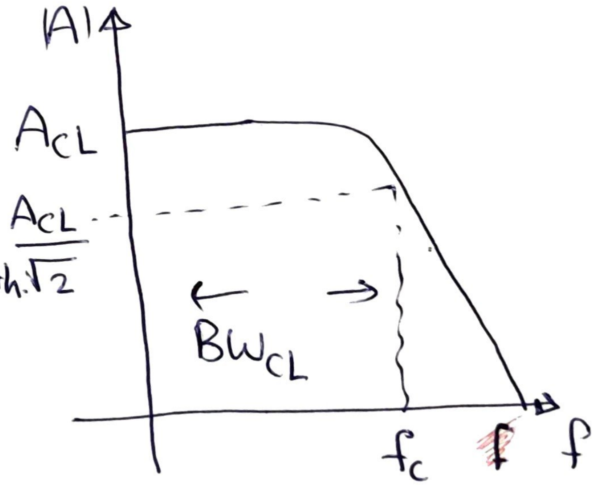


*close loop :-

A_{CL} = close loop gain

$f_c(CL) = BW_{CL}$ = Closed loop bandwidth.$\sqrt{2}$

$BW_{CL} = \beta f_t = A_{OL} f_c(OL)$



β is feed back ratio $\Rightarrow \beta = \frac{R_g}{R_g + R_f}$

For inverting and non inverting amplfier.

uency response

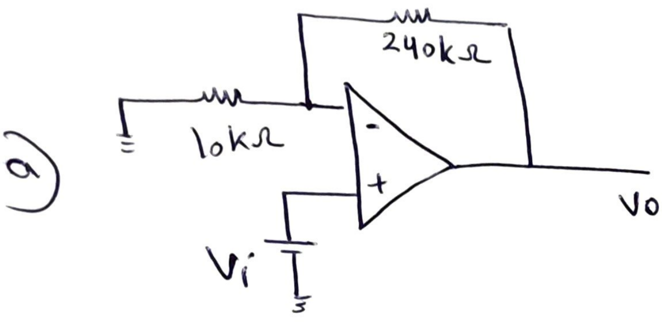
Example :-

Each of the amplifier shown has an open loop gain bandwidth product equal to 1MHz.

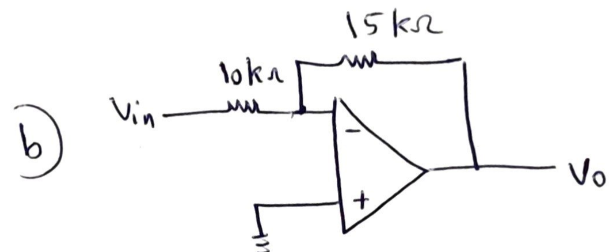
1) find the closed loop cutoff frequencies.

2) Draw the frequency response of each circuit.

a)



b)



Sol :-

$f_t = 1MHz$

$f_{o(cl)} = BW_{CL} = \beta f_t$

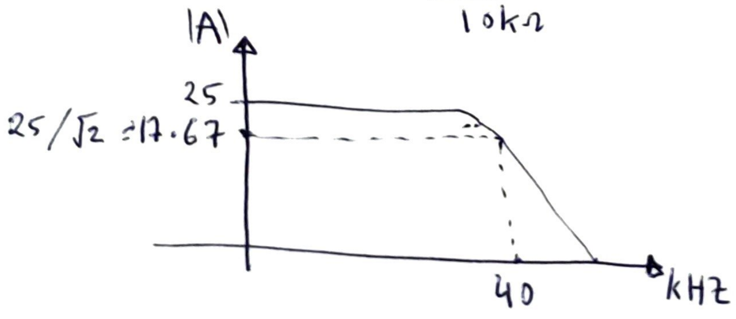
a) $\beta = \frac{10k\Omega}{10k\Omega + 240k\Omega} = \frac{1}{25} = 0.04$

$BW_{CL} = 0.04 \times 1MHz = 40kHz$

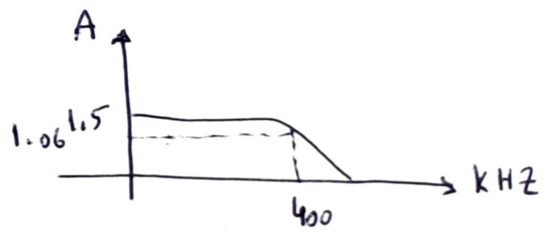
b) $\beta = \frac{10k\Omega}{10k\Omega + 15k\Omega} = \frac{10}{25} = 0.4$

$BW_{CL} = 0.4 \times 1MHz = 400kHz$

2) a) $A = 1 + \frac{240k\Omega}{10k\Omega} = 25$

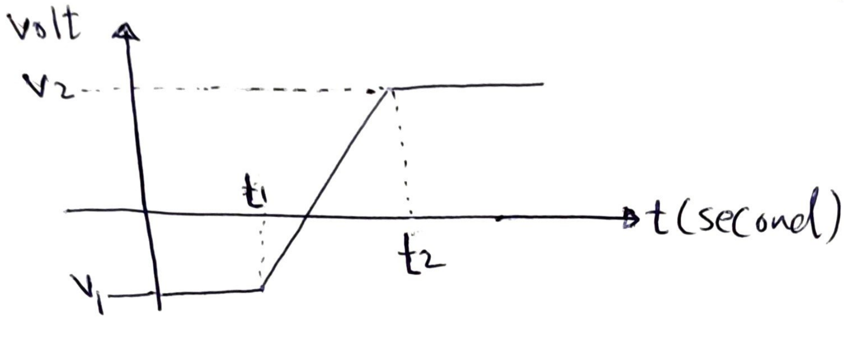


b) $A = -\frac{15k\Omega}{10} = -1.5$



Slew Rate

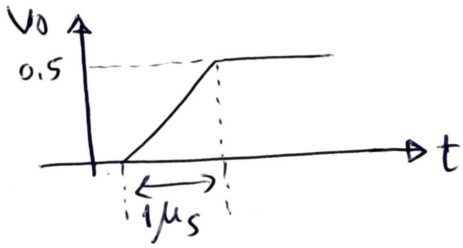
The slew rate is the maximum possible rate at which the op amp output voltage can change (V/s)



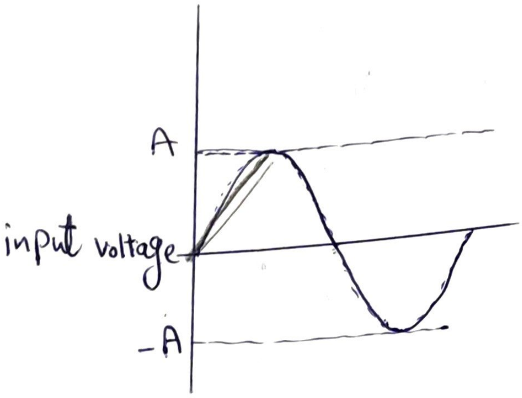
$$\text{rate change of op amp function} = \frac{V_2 - V_1}{t_2 - t_1}$$

$$= \frac{dV}{dt} \; V/s \leq SR \quad \text{[For no distortion]}$$

SR ⇒ op amp 741 = 0.5 V/μsec

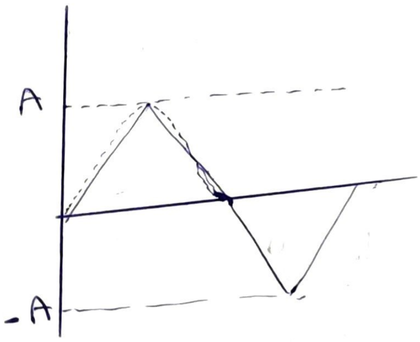


* Slew rate



$\boxed{741}$

$SR = 0.5\ V/\mu s$



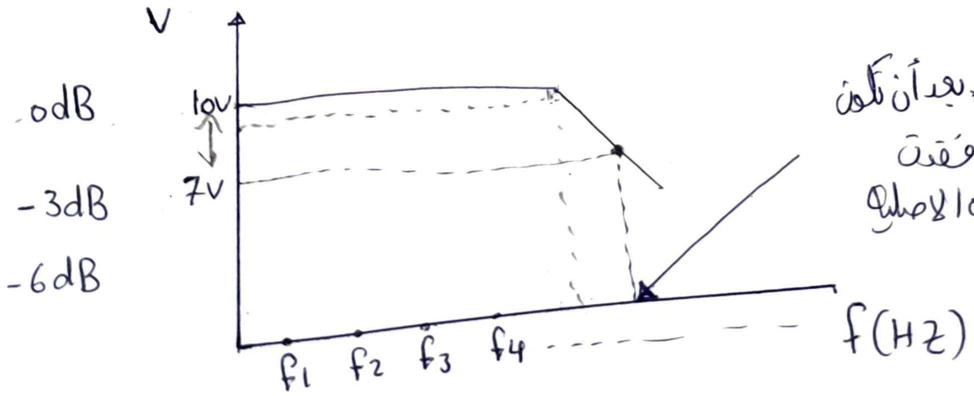
Slope of midum voltage

$$SR = \frac{d V_{out}}{dt}$$

* frequency response:

at 10V ⇒ $P = \frac{V_{out}^2}{R} = 100W$

at 7V ⇒ $P = 49W$



التردد [redacted] بعد أن تكون
اشارة الخرج فقدت
نصف القدرة الاصلية

تردد منخفض → تردد مرتفع

$$dB = 20 \log\left(\frac{V_o}{V_i}\right)$$

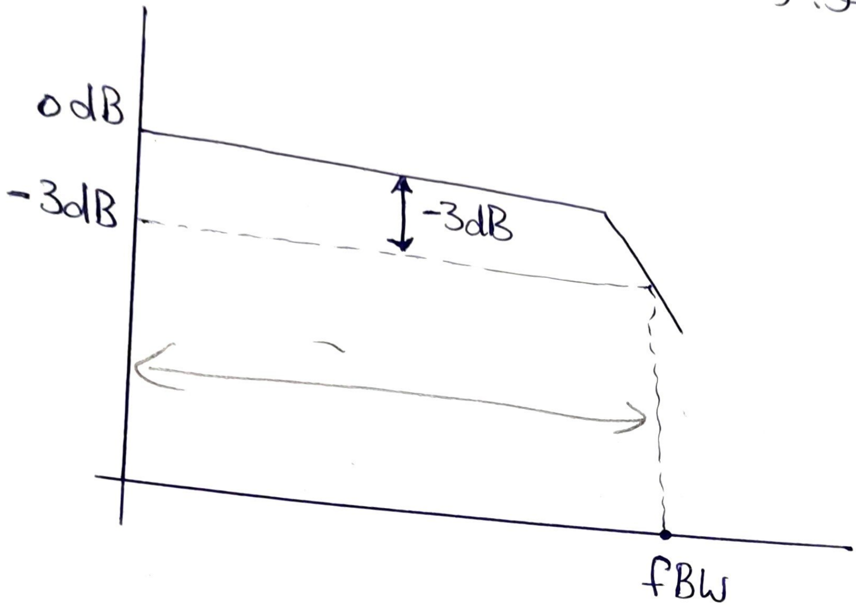
$$6\ dB = 10 \log\left(\frac{P_{out}}{P_{in}}\right)$$

Vi	Vout	النسبة الكسب/الخسارة	المقدار بـ dB	علاقتها بالقدرة
10V	20V	2	6db	4 اضعاف
10V	14.1V	1.41	3dB	ضعف
10V	10V	1	0dB	القدرة نفسها
10V	7V	0.7	-3dB	فقد نصف القدرة
10V	5V	0.5	-6dB	ربع القدرة

كل 3dB سيكون هناك كسب أو فقد في القدرة بمقدار الضعف او النصف

* Bandwidth

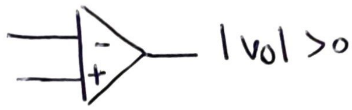
هو عبارة عن حزمة ترددات أو أكبر تردد يمكن للمكبر أن يعمل عنده بكفاءة



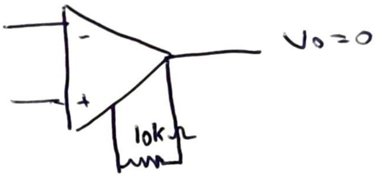
هذا أكبر تردد يمكن أن يتعامل معه المكبر

* offset Currents and Voltages

1) offset voltage



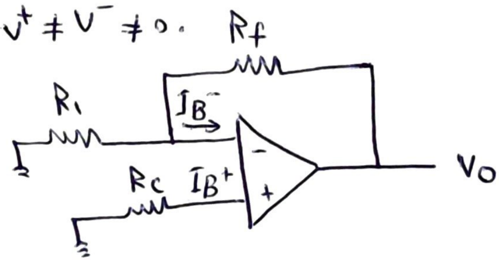
The offset voltage can be reduced by adjusting the 10kΩ ~~Vera~~ Variable resistance until $V_o = 0$



2) offset current

The bias current $I_B^+, I_B^- \neq 0$ & $V^+ \neq V^- \neq 0$.

The best value $R_c = R_f // R_1$



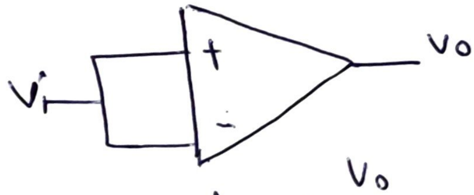
input offset current

$$I_{io} = I_B^+ - I_B^-$$

Common mode rejection ratio (CMRR)

A_{OL} : open loop gain

A_{CM} : Common mode rejection gain



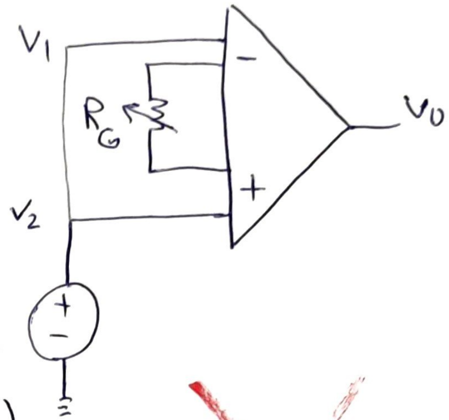
$$CMRR = \left| \frac{A_{OL}}{A_{CM}} \right|$$

$$A_{CM} = \frac{V_o}{V_i}$$

$$CMRR_{dB} = 20 \log \left[\frac{|A_{OL}|}{|A_{CM}|} \right]$$

The best op amp has very high CMRR

* Common-mode Rejection Ratio [CMRR]



$$V_o = A_v(V_2 - V_1) = \left(1 + \frac{2R}{R_G}\right)(V_2 - V_1)$$

جهد مشترك

Common mode voltage :-

$V_1 = V_2 = V_C \Rightarrow V_o = 0$

الداخلين انهما لما تكونوا متشابهين يطلع 0

غير على Common mode Gain $A_c = 0$ ← $\frac{V_o}{V_s} = \frac{0}{V_s} = 0$

- Differential voltage : if $V_1 \neq V_2 \therefore V_o = A_v(V_2 - V_1)$
- Differential Gain of the Amplifier : $A_d = A_v$
- Common mode Rejection Ratio (CMRR) :

$$CMRR = \frac{A_d}{A_c}$$

A_d → differential gain

A_c → لازم تكون كبيرة

A_c → لو هادي صفر : CMRR تكون ∞ يعني شي كويس

عادة CMRR تكون اقل من 100 ومن بعض الاحيان تكون 10000 في حالات a high quality biopotential amp.

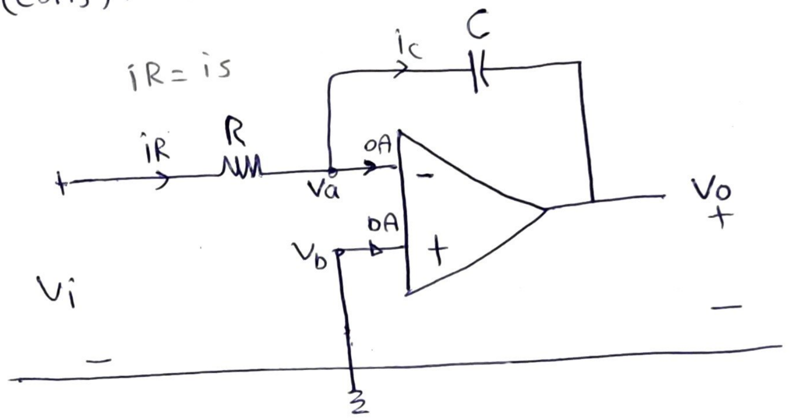
$$CMRR(dB) = 20 \log_{10} \frac{A_d}{A_c}$$

* Integrator op-Amp

Important op Amp Circuits that use energy-storage elements include integrator and differentiators. these op Amp Circuits often involve resistors and Capacitors; inductors (Coils) tend to be more bulky and expensive.

(ti) زمن التكامل

$$V_o(t) = -\frac{1}{RC}\int_0^t V_i \, dt$$



إستنتاج القانون :-

$i_R = i_c$ Ideal op-Amp

$$\frac{V_i - V_a}{R} = C\frac{dv_c}{dt}$$

$$= C\frac{d(V_a - V_o)}{dt}$$

$V_a = V_b = 0$

$$\therefore \frac{V_i}{R} = -C\frac{dv_o}{dt}$$

$$dv_o = -\frac{1}{RC} V_i \, dt$$ تكامل الطرفين

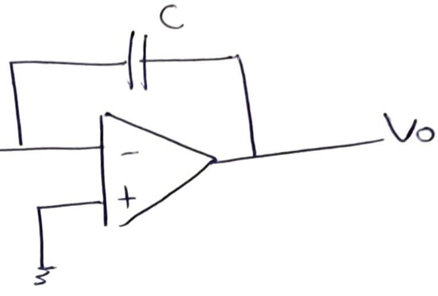
$$\int_0^t dv_o = -\frac{1}{RC}\int_0^t V_i \, dt$$

$$V_o(t)\Big|_0^t = -\frac{1}{RC}\int_0^t V_i \, dt$$

$$V_o(t) - V_o(0) = -\frac{1}{RC}\int_0^t V_i \, dt$$

Ex:- 1) The integrator has $R = 100\ k\Omega$, $C = 20\ \mu f$ Determine the output voltage when a dc voltage of 10 mV is applied at $t = 0$. Assume that the op amp is initially nulled.

Solution :-



∵ The op amp initially nulled

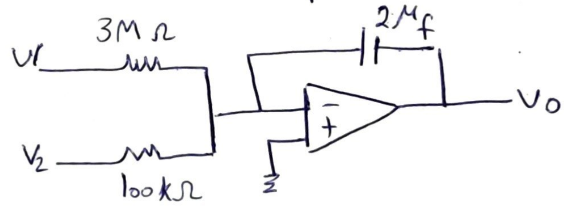
∴ $V_o(0) = 0$

$$V_o(t) - V_o(0) = \frac{-1}{RC} \int_0^t V_i\, dt$$

$$V_o(t) = \frac{-1}{100 \times 10^3 \times 20 \times 10^{-6}} \int_0^t 10 \times 10^{-3}\, dt$$

$$= -5t \quad mV$$

2) if $V_1 = 10 \cos 2t$ mV and $V_2 = 0.5t$ mV, find Vo in the op Amp circuit. Assume that the voltage across the capacitor is initially zero.



$$V_o(t) = -\frac{1}{R_1 C} \int_0^t V_1\, dt - \frac{1}{R_2 C} \int_0^t V_2\, dt$$

$$V_o(t) = -\frac{1}{3 \times 10^6 \times 2 \times 10^{-6}} \int_0^t 10 \cos 2t\, dt - \frac{1}{100 \times 10^3 \times 2 \times 10^{-6}} \int_0^t 0.5\, t\, dt$$

نعوض مرة بـ (t) ومرة بـ (0)

$$= -\frac{1}{6} \times \frac{10}{2} \sin(2t)\Big|_0^t - \frac{1}{0.2} \times \frac{0.5}{2} t^2 \Big|_0^t$$

$$= -\frac{5}{6} \sin 2t - \frac{5}{4} t^2 \quad mV$$

Solution 2

$$V_c = V_a - V_o$$

$$i_1 + i_2 = i_c$$

$$\frac{V_1 - V_a}{R_1} + \frac{V_2 - V_a}{R_2} = C\frac{d(V_1 - V_o)}{dt}$$

$$dV_o = -\frac{V_1}{R_1 C}dt - \frac{V_2}{R_2 C}dt$$

$$\int_0^t dV_o = -\frac{1}{R_1 C}\int_0^t V_1\,dt - \frac{1}{R_2 C}\int_0^t V_2\,dt$$

$$\therefore V_o\Big|_0^t = -\frac{1}{R_1 C}\int_0^t V_1\,dt - \frac{1}{R_2 C}\int_0^t V_2\,dt$$

$$V_o(t) - V_o(0) = -\frac{1}{R_1 C}\int_0^t V_1\,dt - \frac{1}{R_2 C}\int_0^t V_2\,dt$$

Integrator:-

Ex:-

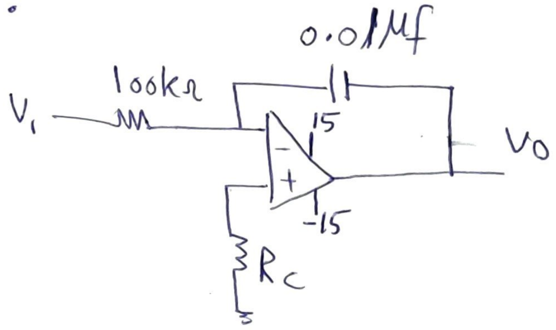
a) Draw the output of ideal integrator show when:-

i- $V_i = 5mV$ (dc)

ii- $V_i = 0.5 \sin 100t$ (v)

iii- $V_i = 0.5 \sin 1000t$ (v)

b) find the best value of R_c.

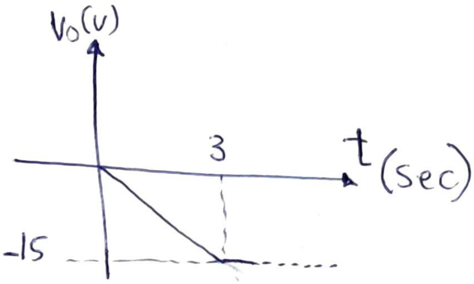


SoL:

i) $V_o = \frac{1}{RC}\int_0^t V_i \, dt$

$V_o = \frac{1}{100k \times 0.01\mu}\int_0^t 5\times10^{-3} \, dt$

$V_o = -1000(5\times10^{-3})t = -5t$ (v)



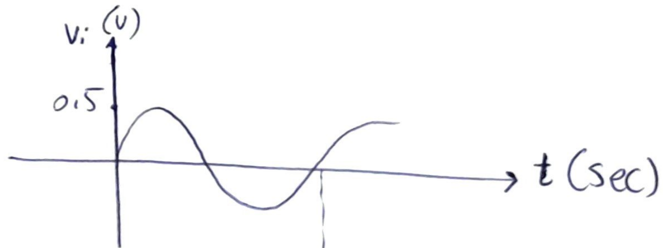
ii) $V_o = -1000\int_0^t 0.5 \sin 100t \, dt$

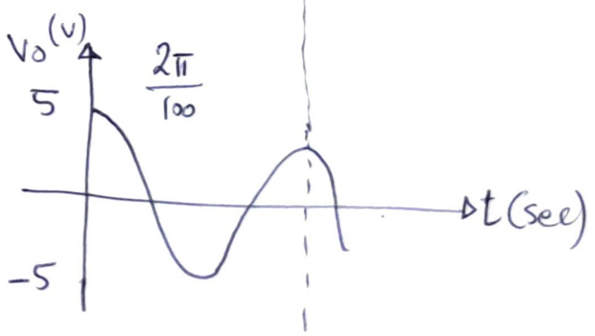
$= -1000\left[\frac{-0.5 \cos 100t}{100}\right] = 5 \cos 100t.$

$\omega = 2\pi f = 100$

$\frac{2\pi}{T} = 100 = 2\pi f$

$T = \frac{2\pi}{100}$

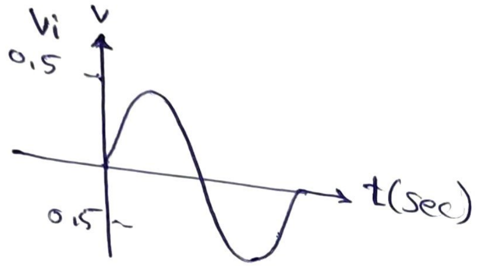


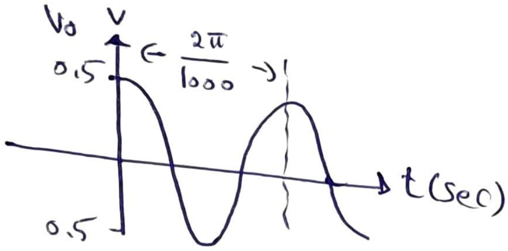


$$V_o = -1000 \int_0^t 0.5 \sin 1000t \, dt$$

$$= -1000 \left[\frac{-0.5 \cos 1000t}{1000} \right] = 0.5 \cos 1000t \ (v)$$

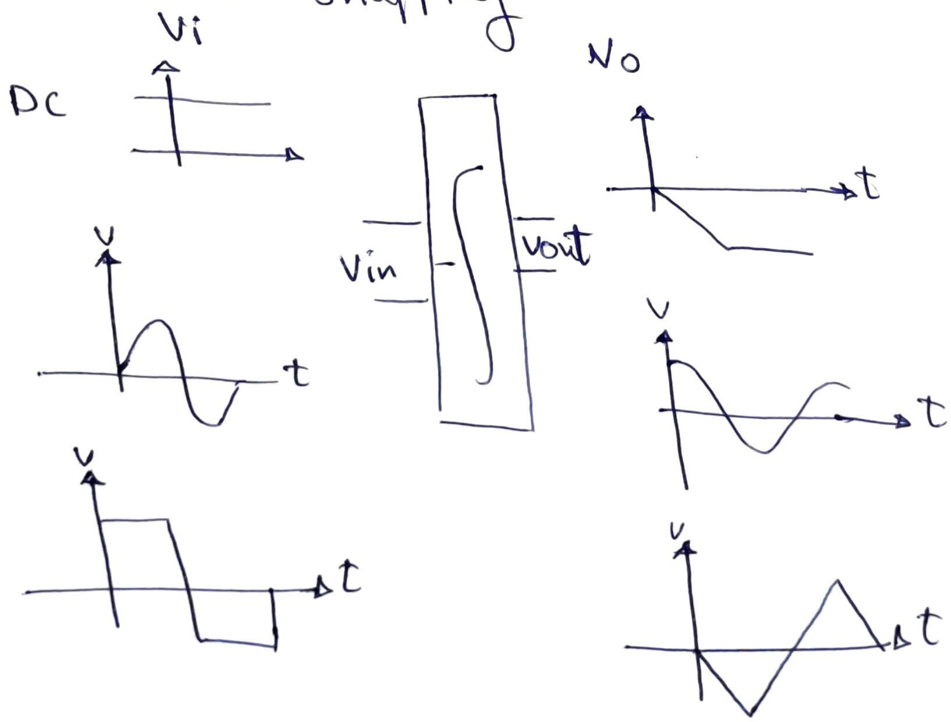
$$T = \frac{2\pi}{1000}$$



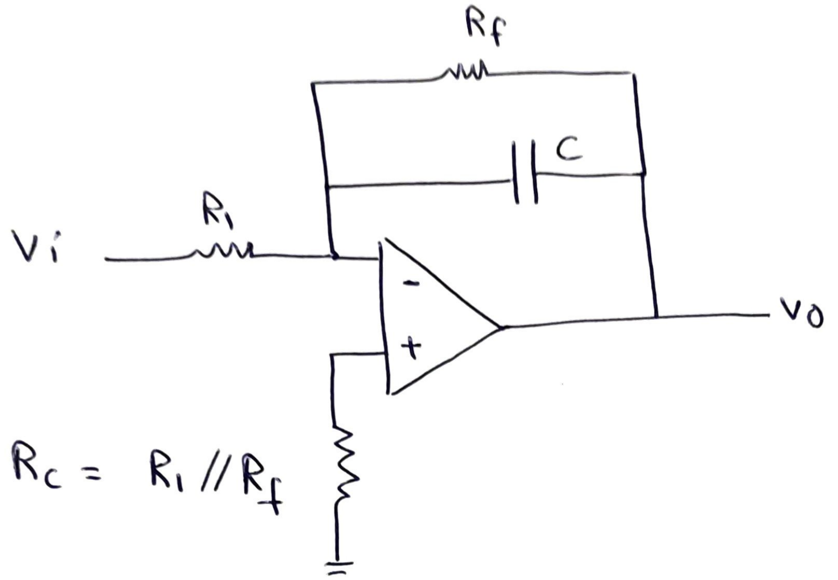


b) $R_C = R_1 = 100 \, k\Omega$

wave shapping



Practical Integrator



$R_c = R_1 // R_f$

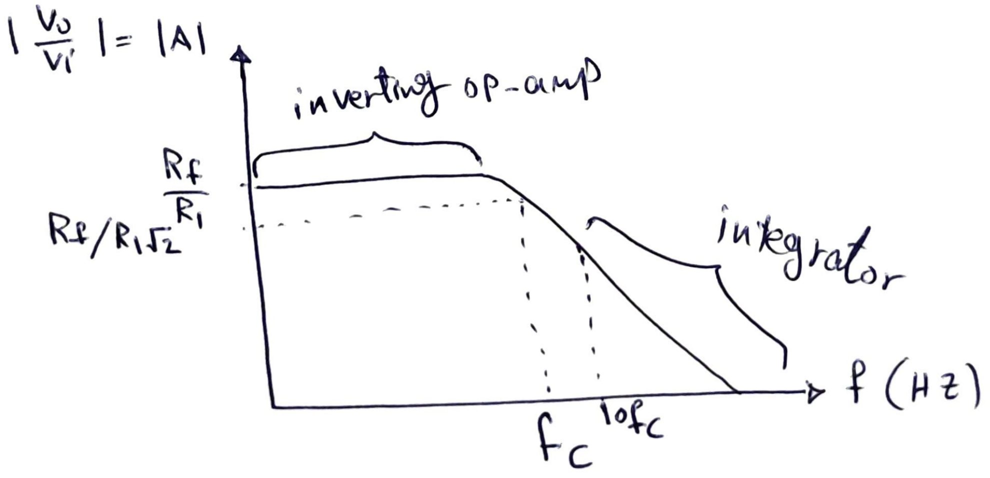
1) $-\frac{R_f}{R_1} v_i$ (dc) at low frequency $f \leq f_c$

2) $\frac{-1}{R_1 C} \int v_i \, dt$ (ac) $f \geq 10 f_c$

$$X_C = \frac{1}{2\pi f C} << R_f$$

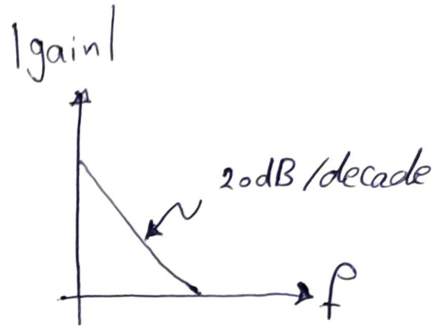
$$f >> \frac{1}{2\pi R_f C} \quad , \text{let } f_c = \frac{1}{2\pi R_f C}$$

$$f >> f_c \Rightarrow f \geq 10 f_c$$



$$gain \propto \frac{1}{f}$$

$$gain = \left|\frac{V_o}{V_i}\right| = \frac{1}{\omega R_1 C}$$



$$V_i = A\sin\omega t \Rightarrow V_o = \frac{-1}{R_1 C}\int A\sin\omega t \cdot dt$$

$$= \frac{-1}{R_1 C}\left[\frac{-A\cos\omega t}{\omega}\right]$$

$$|gain| = \left|\frac{V_o}{V_i}\right| = \frac{-\frac{1}{R_1 C}\left[\frac{-A\cos\omega t}{\omega}\right]}{A\sin\omega t}$$

$$\therefore |gain| = \frac{1}{R_1 C \omega}$$

Ex:

a) Design a practical integrator that

1. Integrates signals with frequencies down to 100 HZ, and
2. Produces a peak output of 0.1V when the input is a 10V peak sine wave having frequency 10kHZ.

b) Find the output when the input is 50mV dc.

c) draw the frequency response of the designed circuit.

Sol:-

$f \geq 10 f_c$

$100\,HZ = 10 f_c \Rightarrow f_c = \frac{100\,HZ}{10} = 10\,HZ = \frac{1}{2\pi R_f C}$

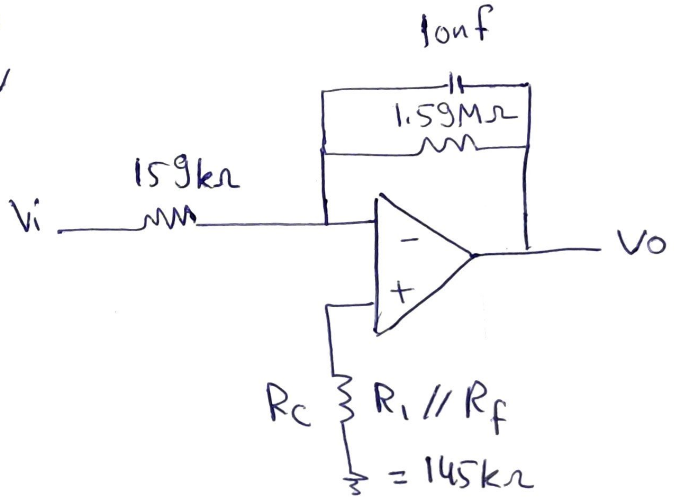
let $C = 10nf \Rightarrow R_f = 1.59\,M\Omega$

$V_{ip} = 10V$, $f = 10kHZ \Rightarrow V_{op} = 0.1V$

$$\text{gain} = \frac{1}{W R_1 C} = \left|\frac{V_o}{V_i}\right| = \frac{0.1v}{10V}$$

$$R_1 = \frac{10}{2\pi \times 10^4 \times 10 \times 10^{-9} \times 0.1}$$

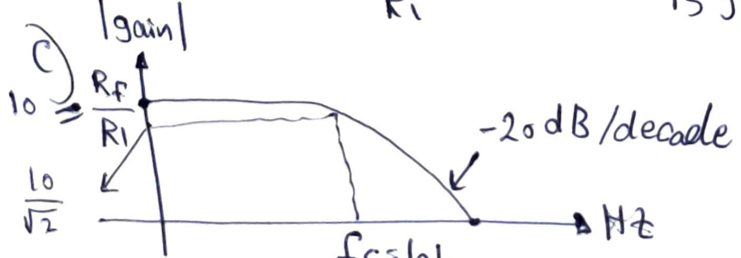
$R_1 = 159\,k\Omega$



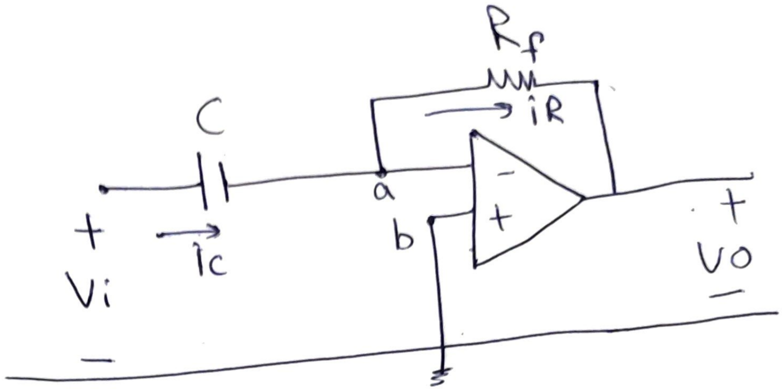
b) $V_i = 50mV$ (dc)

$$V_o = \frac{-R_f}{R_1} V_i = \frac{-1.59M\Omega}{159k\Omega}(50mV) = 0.5V$$

c)



Ideal differentiator:-



$V_c = V_i - V_a$

$i_c = i_R$

$$C \frac{dV_c}{dt} = \frac{V_a - V_o}{R}$$

$\because V_c = V_i - V_a$

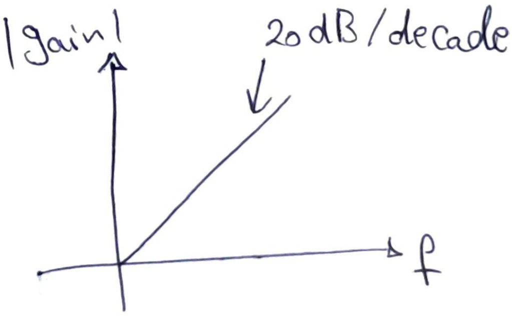
$$\therefore C \frac{d(V_i - V_a)}{dt} = \frac{V_a - V_o}{R}$$

$V_a = V_b = 0$ for Ideal op-amp

$$C \frac{dV_i}{dt} = \frac{-V_o}{R}$$

$$-\frac{V_o}{R} = C \frac{dV_i}{dt}$$ (نضرب الطرفين فى $-R$)

$$V_o = -RC \frac{dV_i}{dt}$$



$$\text{gain} = \left| \frac{V_o}{V_i} \right| = \omega C R_f = 2\pi f C R_f$$

differentiator:-

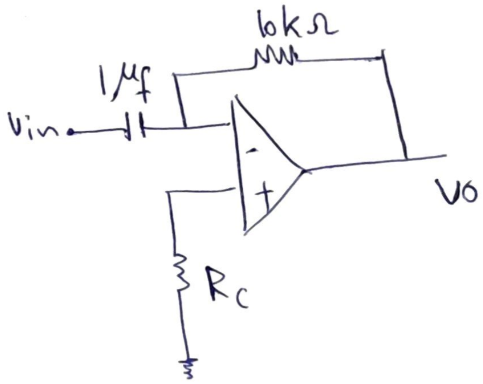
Example:-

for the circuit shown draw the output where,

1) $V_i = 0.2 \sin 10^2 t$ [v]

2) $V_i = 0.2 \sin 10^3 t$ [v]

find the value of Rc.



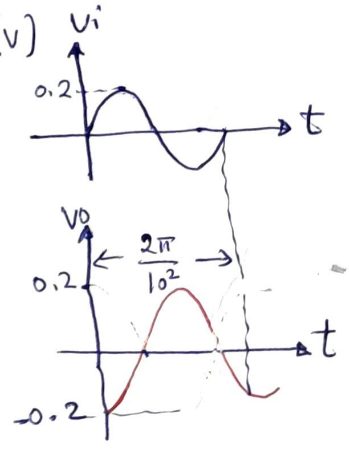
Sol:-

$$V_o = -R_f C \frac{dV_i}{dt}$$

1) $$V_o = -10 \times 10^3 \times 10^{-6} \left(\frac{d\, 0.2 \sin 10^2 t}{dt} \right)$$

$$V_o = -10 \times 10^3 \times 10^{-6} \times 10^2 \times 0.2 \cos 10^2 t \text{ (v)}$$

$$= -0.2 \cos 10^2 t \text{ (v)}$$



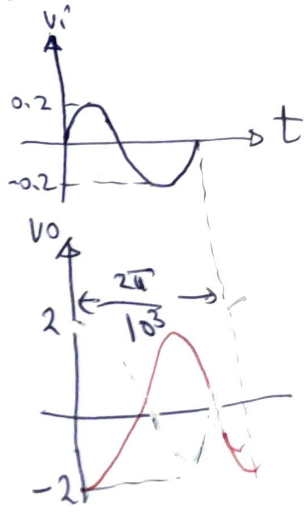
$\omega = 2\pi f = 10^2$

$f = \frac{10^2}{2\pi}$

$T = \frac{1}{f} = \frac{2\pi}{10^2}$

2) $$V_o = -10 \times 10^3 \times 10^{-6} \times 10^3 \times 0.2 \cos 10^3 t \text{ [v]}.$$

$$= -2 \cos 10^3 t \text{ [v]}$$



$R_c = R_f = 10k\Omega$

#

Ex:-

The differentiator in fig (1) has $R = 100\,k\Omega$ and $C = 0.1\,\mu f$
Given that $v_i = 3t$ V, determine the output V_o.

$$V_o = -RC \frac{dv_i}{dt}$$

$$= -100 \times 10^{3} \times 0.1 \times 10^{-6} \frac{d}{dt} 3t$$

$$= -0.01 \times 3 = -0.03\,V = -30\,mV$$

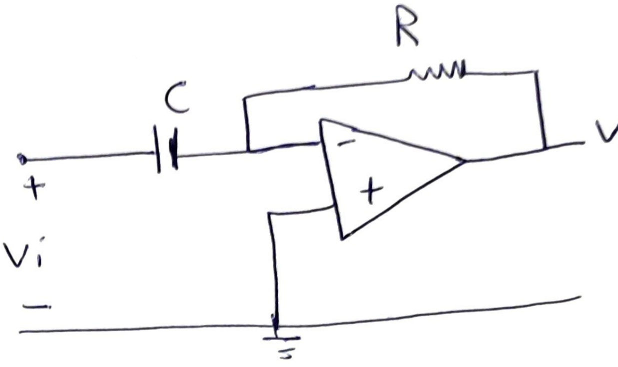
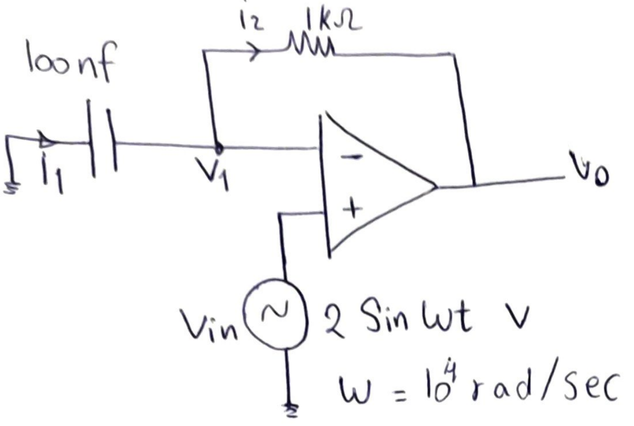


figure "1"

find $V_o(t)$



Solution :- $i_1 = i_2$

$$V_c = 0 - V_1$$

$$C \cdot \frac{dv_c}{dt} = \frac{V_1 - V_o}{R}$$

$$100 \times 10^{-9} \left(\frac{d(0 - V_1)}{dt} \right) = \frac{2 \sin \omega t - V_o}{1000\,\Omega}$$

$$100 \times 10^{-9} \cdot \frac{d(-2 \sin \omega t)}{dt} = \frac{2 \sin \omega t - V_o}{1000}$$

$$100 \times 10^{-9} (-2\omega \cos \omega t) = \frac{2 \sin \omega t - V_o}{1000}$$

$$1000 \times 100 \times 10^{-9} (-2 \times 10^4 \cos \omega t) = 2 \sin \omega t - V_o$$

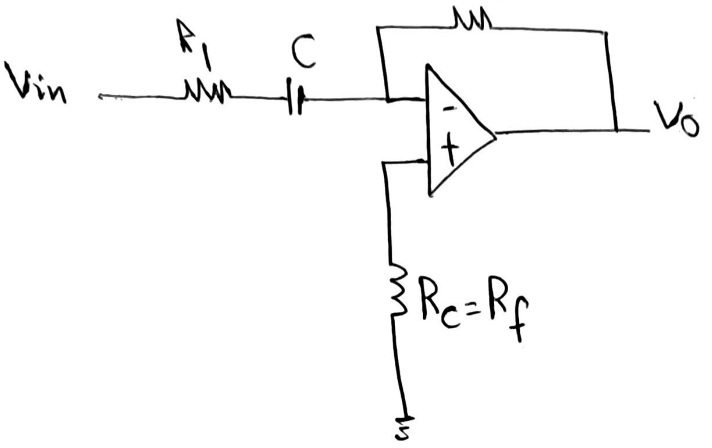
$$-2 \cos \omega t = 2 \sin \omega t - V_o$$

$$V_o = 2 \sin \omega t + 2 \cos \omega t$$

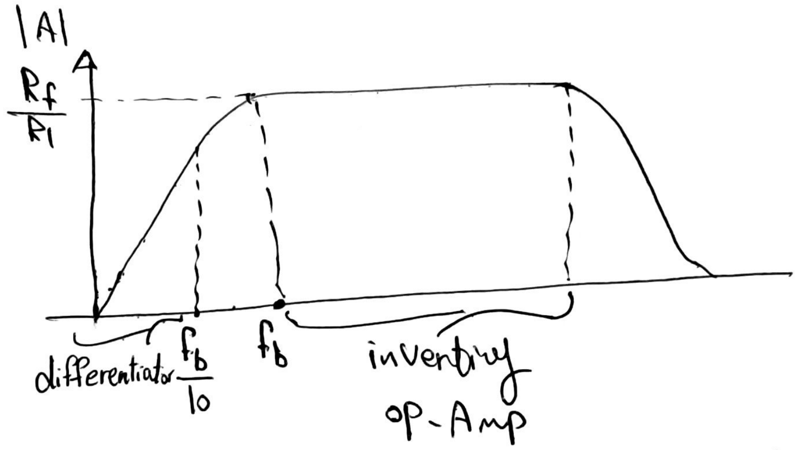
$$= 2 \left[\sin \omega t + \cos \omega t \right]$$

#

* practical differentiator :-



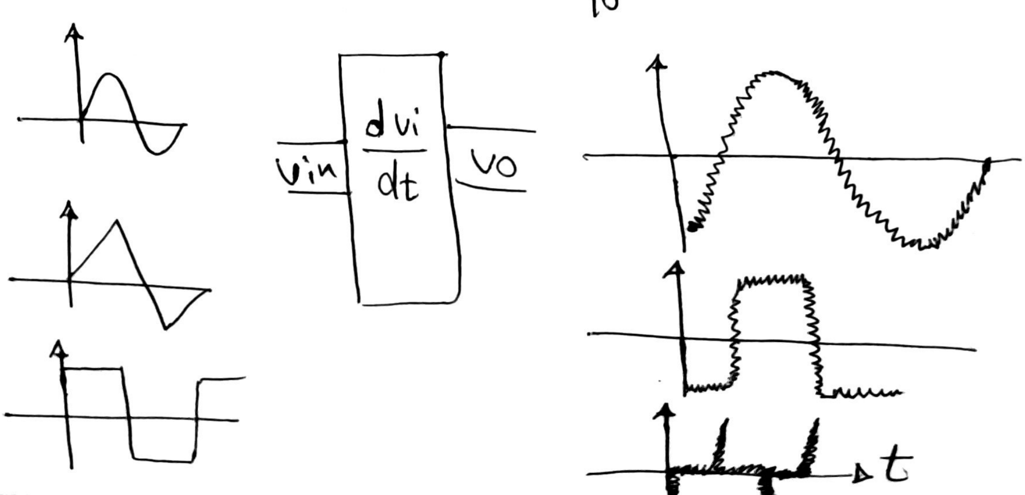
$$\begin{cases} -R_f C \dfrac{dv_i}{dt} & \text{low frequency} \quad f \ll \dfrac{f_b}{10} \\ -\dfrac{R_f}{R_1} v_i & \text{High frequency} \quad f \gg f_b \end{cases}$$



$$\frac{1}{2\pi f C} = X_C > R_1$$

$$f \ll \frac{1}{2\pi R_1 C} \quad \text{let} \quad f_b = \frac{1}{2\pi R_1 C}$$

$$f \ll f_b \quad , \quad f \leq \frac{f_b}{10}$$



Example:-

a) Design a practical differentiator that will differentiate signals with frequencies up to 200 HZ the gain at 10 HZ for sine wave should be 0.1.

b) Draw the frequency response of the designed differentiator if the op-amp used has a unity gain frequency of 1MHZ

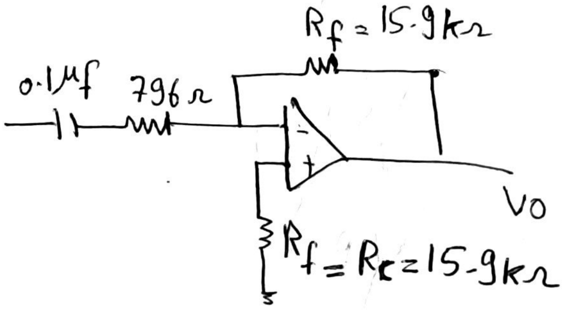
c) Draw Vo where: i) $V_i = 0.1 \sin 2\pi * 10^4 t$ (V)

ii) $V_i = 0.2 \sin 2\pi \times 10^2 t$ (V)

Sol:-

$$\frac{f_b}{10} = 200 \implies f_b = 2000\ HZ = 2kHZ$$

at 10 HZ   A = 0.1   Sin Wave



$$f_b = \frac{1}{2\pi R_1 C} = 2000$$

let $C = 0.1\,\mu f$

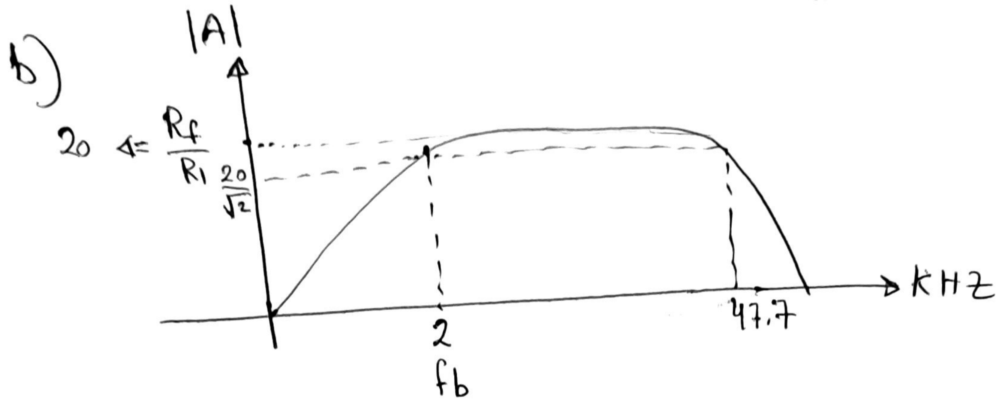
$$R_1 = \frac{1}{2\pi \times 0.1 \times 10^{-6} \times 2000} = 796\,\Omega$$

gain $= \omega R_f C \implies$ at 10 HZ = 0.1

$$0.1 = 2\pi \times 10 \times R_f \times 0.1 \times 10^{-6}$$

$$R_f = \frac{0.1}{2\pi \times 10 \times 0.1 \times 10^{-6}} = 15.9\,k\Omega$$

b)



$$\frac{R_f}{R_i} = \frac{15.9k\Omega}{796\Omega} \simeq 20$$

$$BW_{CL} = \beta f_t = \frac{R_1}{R_1+R_f}(f_t) = \frac{796}{796+15.9}(1\times10^6)$$

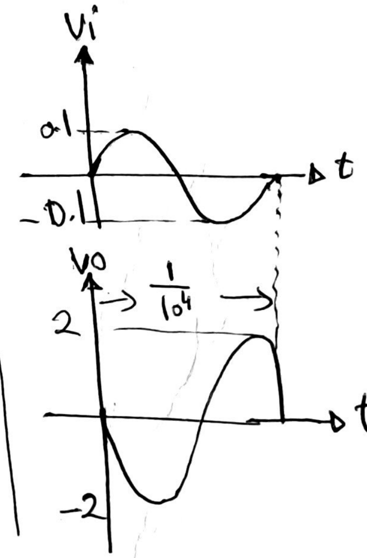
$= 47.7kHZ$

c) i) $f = 10^4 > f_b$ ∴ inverting amplifier

$$V_o = \frac{-R_f}{R_1}(v_i)$$

$= -20\,(0.1 \sin 2\pi 10^4 t\ (v))$

$= -2 \sin 2\pi 10^4 t\ [v]$



ii) $V_i = 0.2 \sin 2\pi \times 10^2 t\ [v]$.

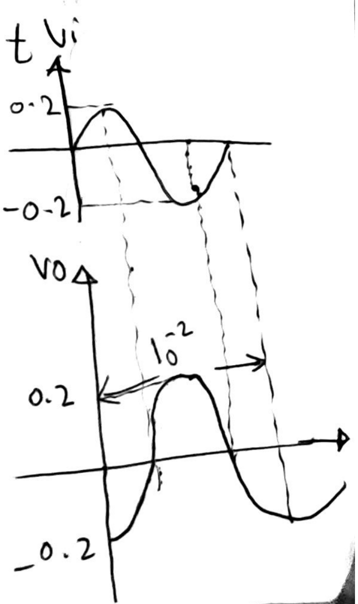
$f = 10^2 = 100 < \frac{f_b}{10}$ ⇒ differentiator

$$V_o = -R_f C \frac{dv_{in}}{dt}$$

$= -15.9k \times 0.1\mu \times [0.2 \times 2\pi \times 100 \cos 2\pi 10^2 t$

$= -0.2 \cos 2\pi 10^2 t\ [V]$

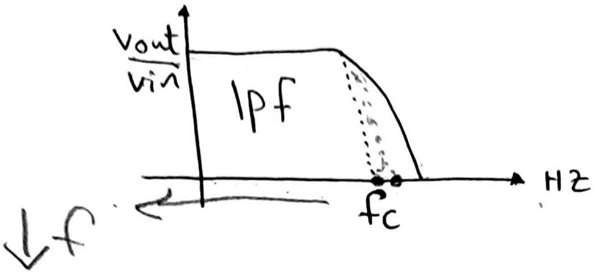
$$T = \frac{1}{f} = \frac{1}{10^2} = 10^{-2}$$



Passive and Active filters:

1) low pass filter :-

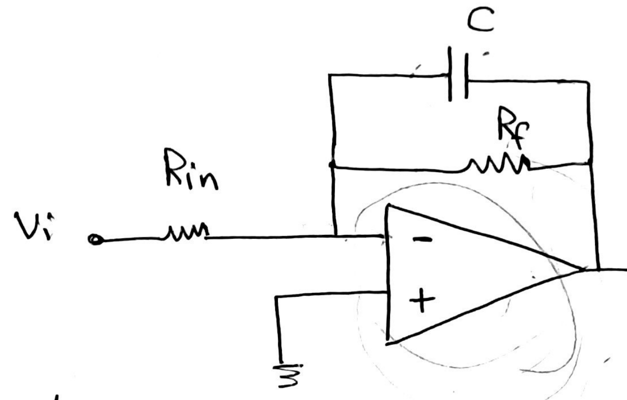
يسمح بمرور الترددات الصغيرة

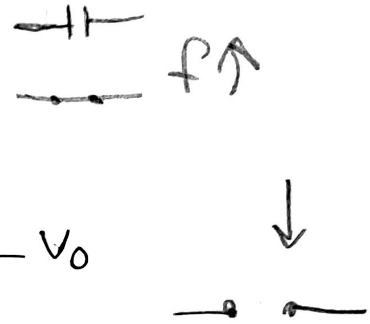


$f_c \Rightarrow$ Critical frequency

التردد الحرج

1)



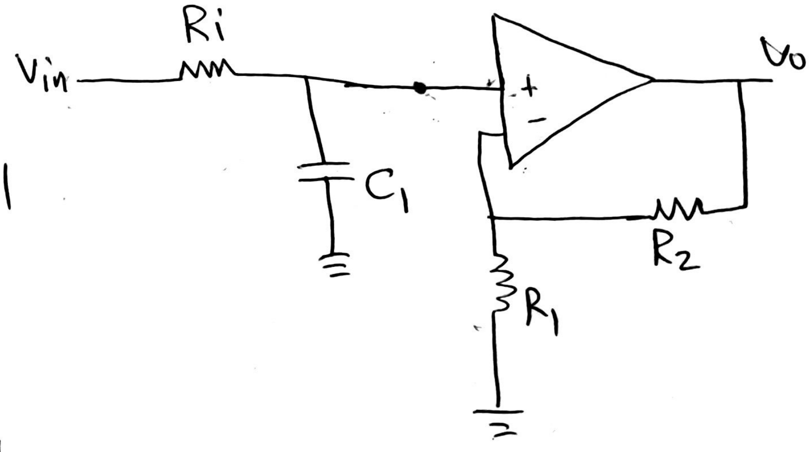


$$f_c = \frac{1}{2\pi R_f C}$$

$$X_C = \frac{1}{2\pi f C}$$

$$Gain = \frac{-R_f \parallel X_C}{R_{in}}$$

2)

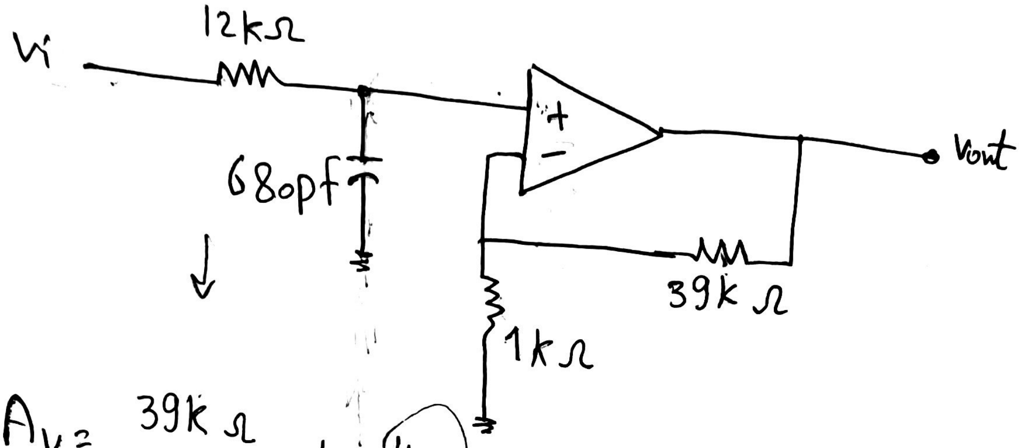


$$A_V = \frac{R_2}{R_1} + 1$$

$$f_c = \frac{1}{2\pi R_{in} C_1}$$

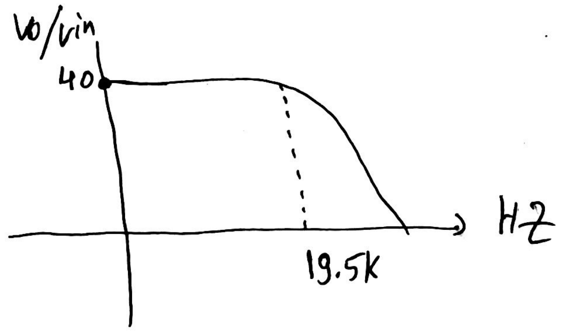
احسب كسب الجهد من الشكل

احسب تردد القطع وارسم الاستجابة الترددية

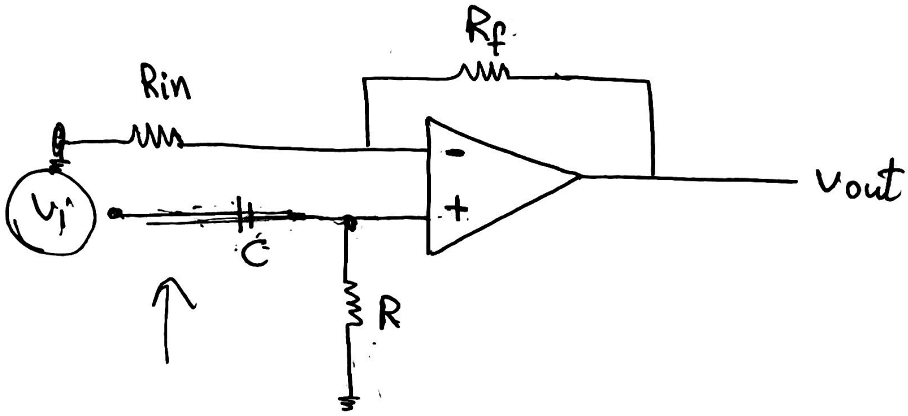


$$A_v = \frac{39k\,\Omega}{1k\,\Omega} + 1 = 40$$

$$f_c = \frac{1}{2\pi\,(12k\Omega)(680pf)} = 19.5\,kHz$$



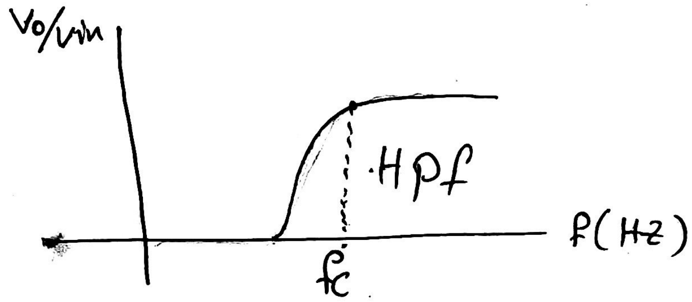
2) High pass filter (HPF)



$$Gain = 1 + \frac{R_f}{R_{in}}$$

$$V_o = V_i\left(1 + \frac{R_f}{R_{in}}\right)$$

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



Ex:-

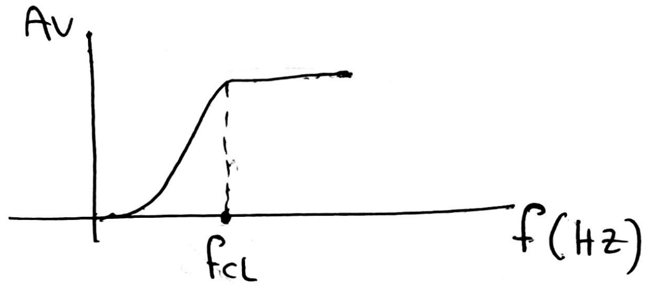
1) Calculate the cutoff frequency of a lpf for $R_1 = 1.2 K\Omega$ & $C_1 = 0.02 \mu f$

Solution:-

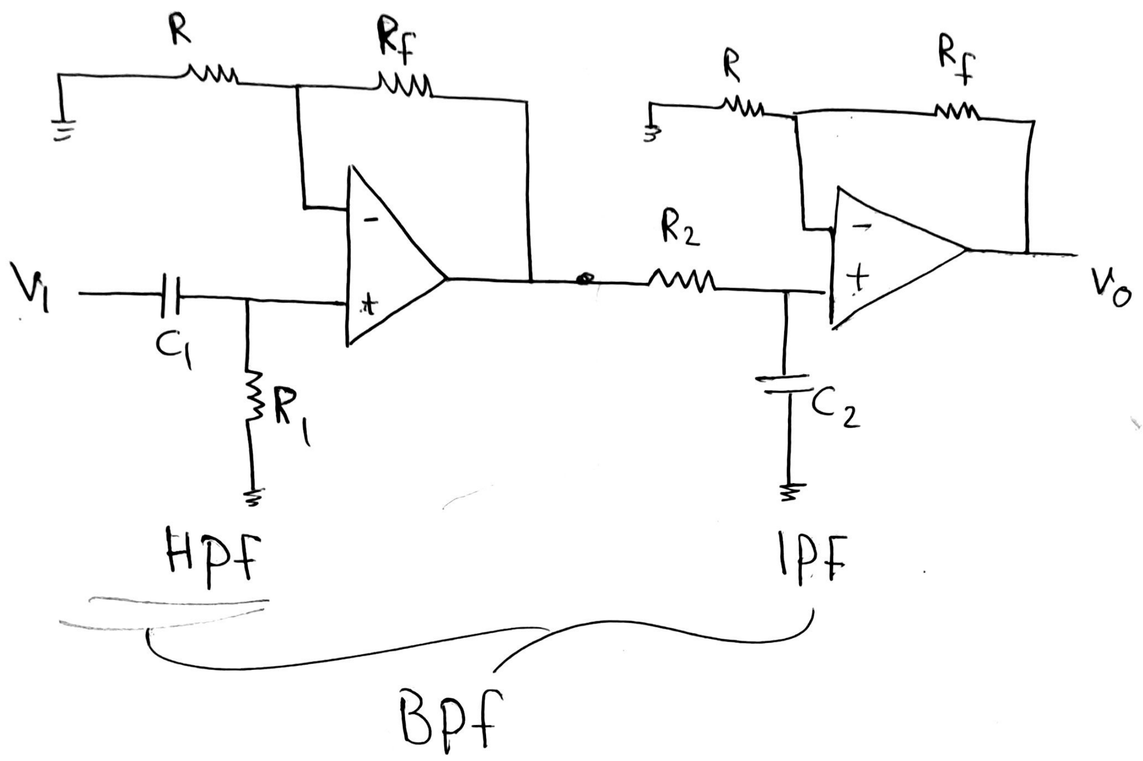
$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(1.2\times10^3)(0.02\times10^{-6})} = 6.63 KHZ$$

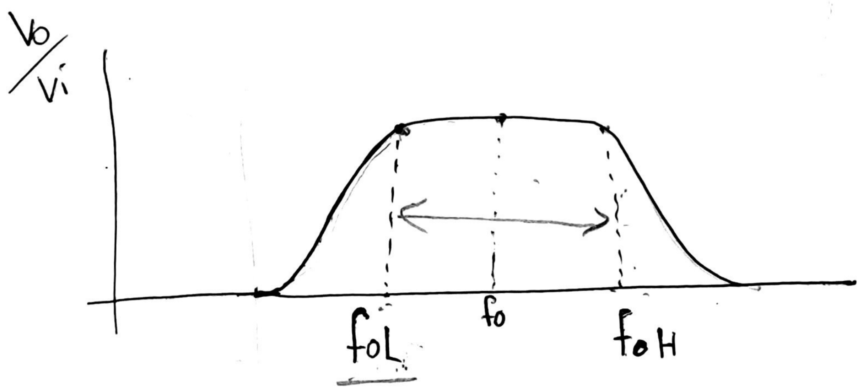
2) Calculate the fc of a HPF for $R_1 = 20 k\Omega$ and $C_1 = 0.02 \mu f$

$$f_{cL} = \frac{1}{2(3.14)(20\times10^3)(0.02\times10^{-6})} =$$



* Bandpass filter :-





تمرر ترددات عالية $f_{oL} = \dfrac{1}{2\pi R_1 C_1}$

$f_o = \sqrt{f_{oL} * f_{oH}}$

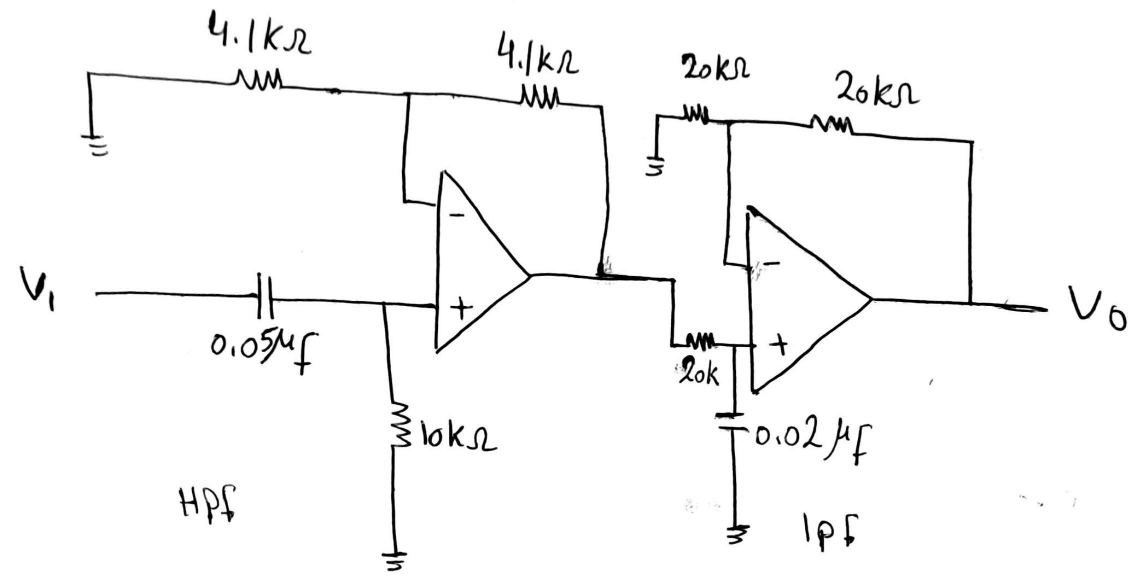
تمرر ترددات منخفضة $f_{oH} = \dfrac{1}{2\pi R_2 C_2}$

$BW = f_{oH} - f_{oL}$

if $f_{oL} < f_{oH}$ Bandpass filter

$f_{oH} < f_{oL}$ Band stop filter

3) Calculate the lower and upper cutoff frequencies of the bandpass filter circuit

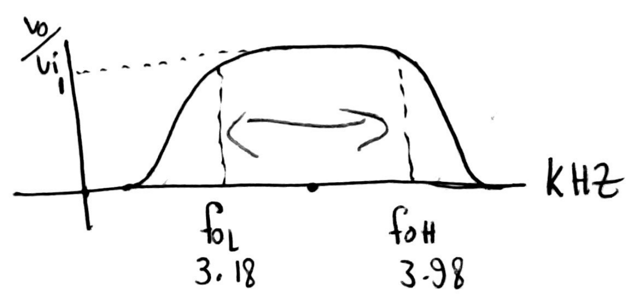


$$f_{oL} = \frac{1}{2\pi R_1 C_1}$$

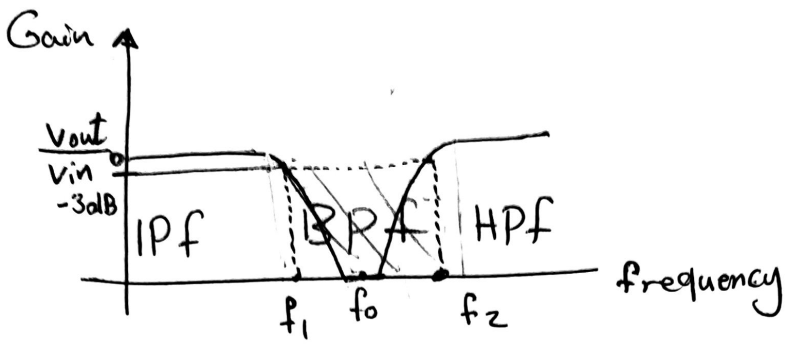
$$= \frac{1}{2(3.14)(10\times10^{3})(0.05\times10^{-6})} = 3.18\ \text{K Hz}$$

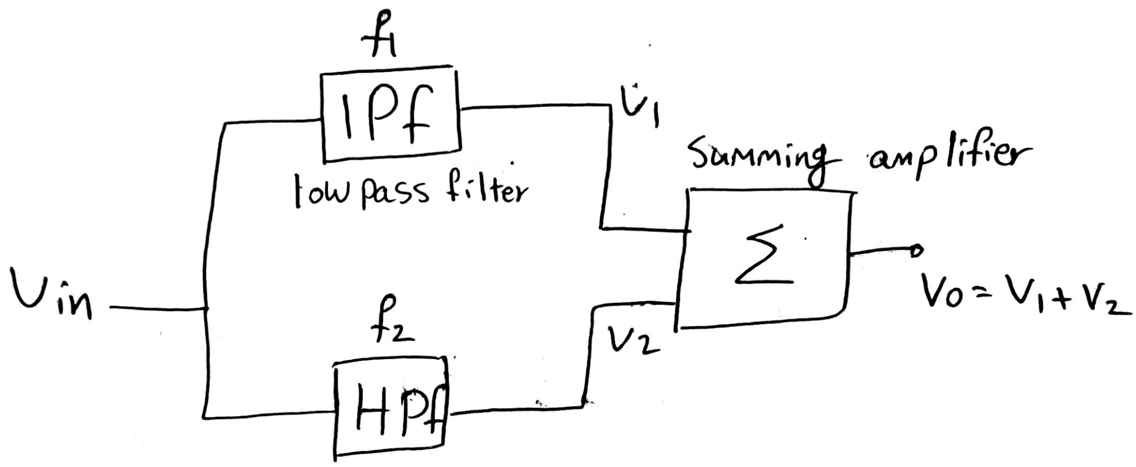
$$f_{oH} = \frac{1}{2\pi R_2 C_2}$$

$$= \frac{1}{2(3.14)(20\times10^{3})(0.02\times10^{-6})} = 3.98\ \text{K Hz}$$



Band Stop filter = Band reject filter

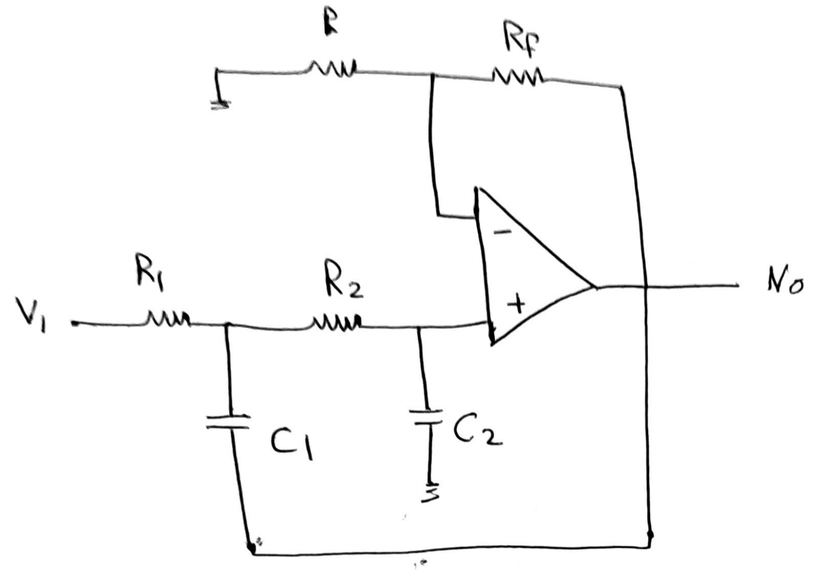


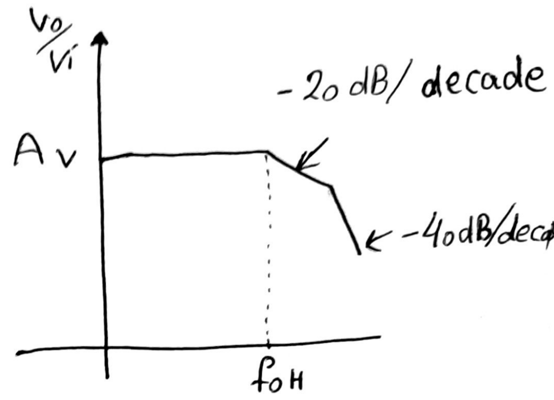


التردد المركزى $f_o = \sqrt{f_1 f_2}$

عرض النطاق $BW = f_2 - f_1$

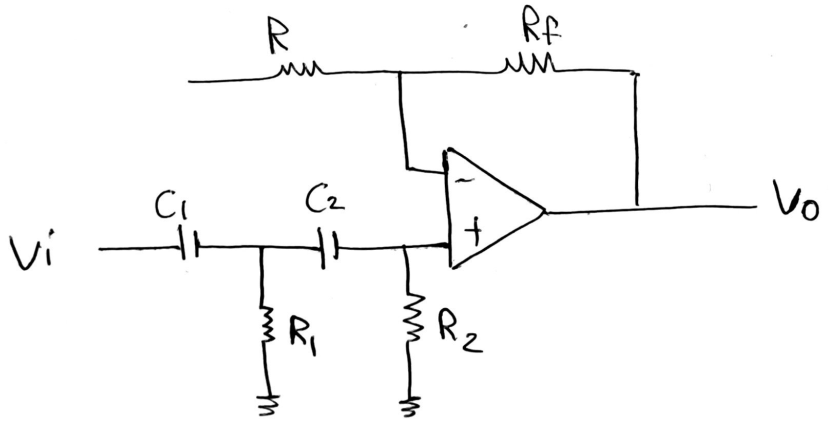
* Second order lPf :-

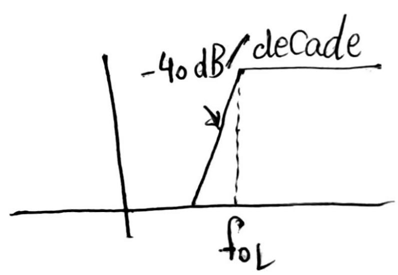




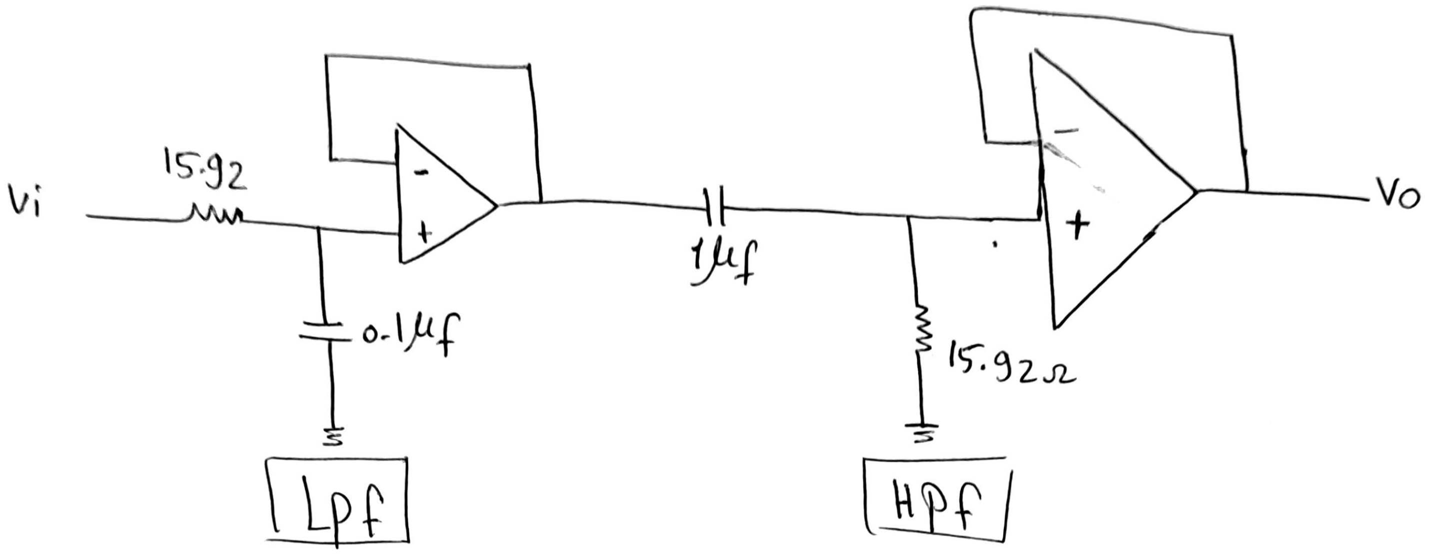
* The circuit voltage gain and cutoff frequency are the same for the second order circuit as for the first order filter circuit except that the filter response drops at a fast rate a second order filter circuit.

* Second order Hpf :-





Ex :-



for the Circuit shown :-

a) What the function of this Circut

b) Draw the frequency response

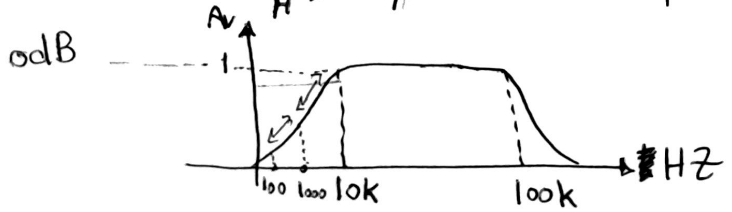
c) find the Gain at 100 HZ

Solution :-

تمرير ترددات عالية $f_{oL} = \dfrac{1}{2(3.14)(1\times10^{-6})(15.9)} = 10\ kHZ$

تمرير ترددات منخفضة $f_{oH} = \dfrac{1}{2(3.14)(0.1\times10^{-6})(15.92)} = 100\ kHZ$

$\because f_{oH} > f_{oL}$ $\therefore$ Band pass filter



$dB = 20 \log \left(\dfrac{V_o}{V_i}\right)$

$= 20 \log(1)$

$= 0$

$G\ (100\ HZ) = 0 - 40\,dB = -40\,dB$

Gain = -40 dB/decade