(1)

(1) Slew rate : $SR = \frac{\Delta V_0}{\Delta t}$ V/μs

(2) CMRR $= \frac{A_d}{A_c} \Rightarrow CMRR(\log) = 20\log_{10}\left\{\frac{A_d}{A_c}\right\}$ dB

negative feed back

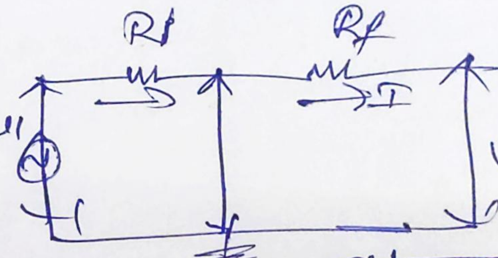
NF

(1) open loop gain of the opamp is very high 2×10^5 for IC741

unsuitable for LIC

(2) not stable & varies with temperature.

Virtual Ground Concept :



$\frac{V_i - V_A}{R}$

$\boxed{V_A = V_B = 0}$

$I = \frac{V_1 - V_A}{R_1} = \frac{V_A - V_0}{R_f}$

$\Rightarrow \boxed{\frac{V_0}{V_1} = -\frac{R_f}{R_1} = \text{Gain}}$

if $V_0 = -10V$

$A_v = 20{,}000$

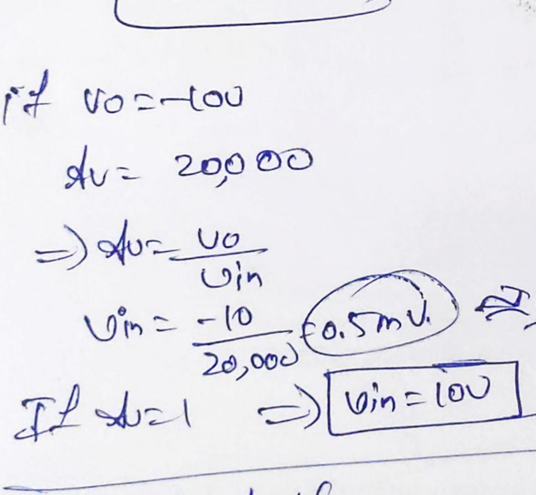
$\Rightarrow A_v = \frac{V_0}{V_{in}}$

$V_{in} = \frac{-10}{20{,}000} = 0.5\,mV \approx 0$

If $A_v = 1 \Rightarrow \boxed{V_{in} = 10V}$

$I = \frac{V_1}{R_1} = -\frac{V_0}{R_f}$

(1) Inverting Amplifier :



WKT $V_A = V_B$ output

& input $I_1 = \frac{V_1 - V_A}{R_1}$ (1) & $I_2 = \frac{V_A - V_0}{R_f}$ (2)

Equating (1) = (2)

$\frac{V_1 - V_A}{R_1} = \frac{V_A - V_0}{R_f}$

$\frac{V_1}{R_1} = \frac{-V_0}{R_f}$

$\Rightarrow \boxed{\frac{V_0}{V_1} = -\frac{R_f}{R_1}}$

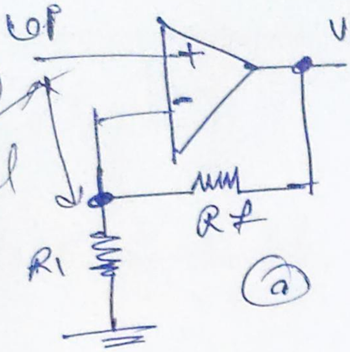
Gain

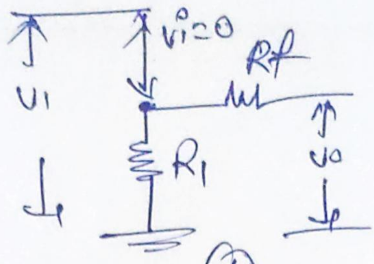
O/P volt of IA $\Rightarrow \boxed{V_0 = \left(-\frac{R_f}{R_1}\right) V_1}$

(2) Non-Inverting Amplifier:

Method 1

Equal



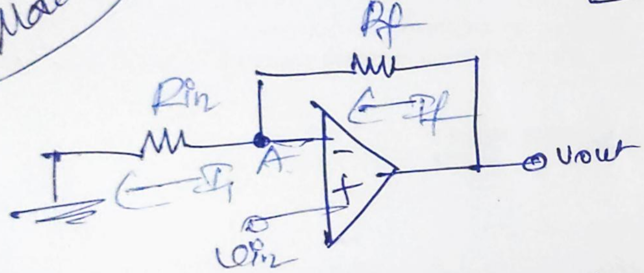


Now Voltage across R_1 is $V_1 = \frac{V_o R_1}{R_1 + R_f}$

$$\Rightarrow V_o = \left(\frac{R_1 + R_f}{R_1}\right) V_1$$

$$\Rightarrow \boxed{V_o = \left(1 + \frac{R_f}{R_1}\right) V_1}$$

Method 2



WKT $V_A = V_{in}$

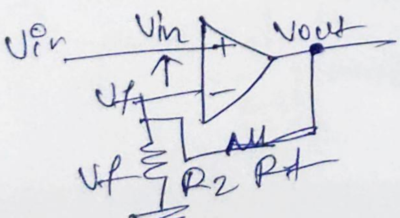
$$V_A = \frac{R_{in} V_{out}}{R_{in} + R_f}$$

$$\Rightarrow \frac{V_{out}}{V_A} = \frac{R_{in} + R_f}{R_{in}}$$

$$\Rightarrow V_{out} = \left(1 + \frac{R_f}{R_{in}}\right) V_A$$

$$\Rightarrow \boxed{A_v = \left(1 + \frac{R_f}{R_{in}}\right)}$$

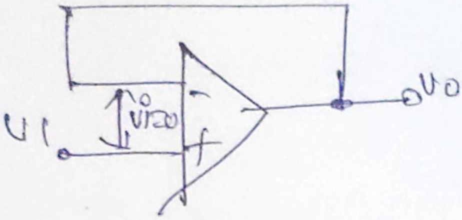
Ideal op-Amp Negative feedback



Closed loop Gain $= \frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_2}$

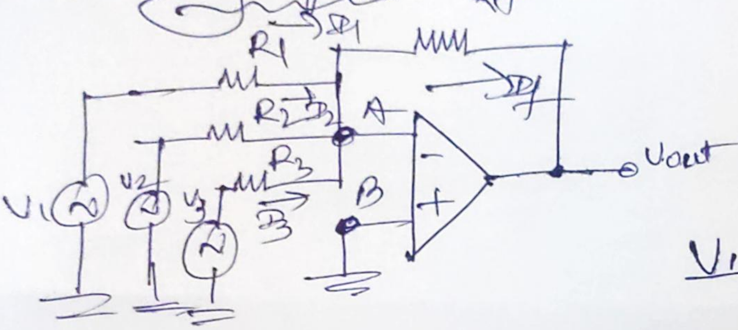
feedback $\beta = \frac{V_f}{V_{out}} = \frac{R_2}{R_f + R_2}$

(3) Unity follower / Voltage follower



here $\boxed{V_o = V_1}$

#(4) Summing Amplifier:



$V_A = V_B$ & KCL at node A

$$I_1 + I_2 + I_3 = I_f$$

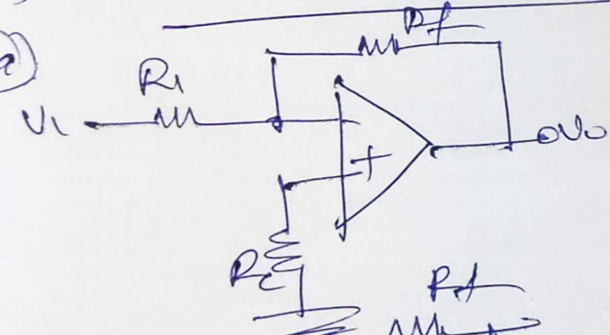
$$\frac{V_1 - V_A}{R_1} + \frac{V_2 - V_A}{R_2} + \frac{V_3 - V_A}{R_3} = \frac{V_A - V_{out}}{R_f}$$

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

$$\Rightarrow \boxed{V_{out} = -R_f\left[\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right]}$$

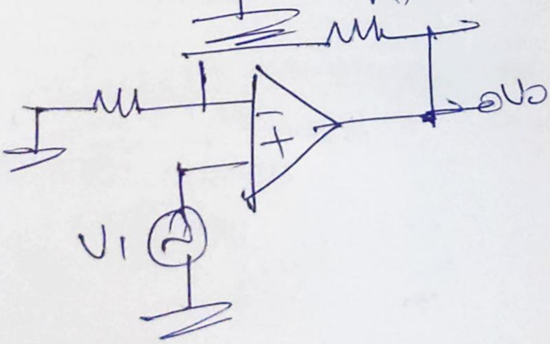
#(5) Constant Gain / fixed Gain Amplifier:

(a)



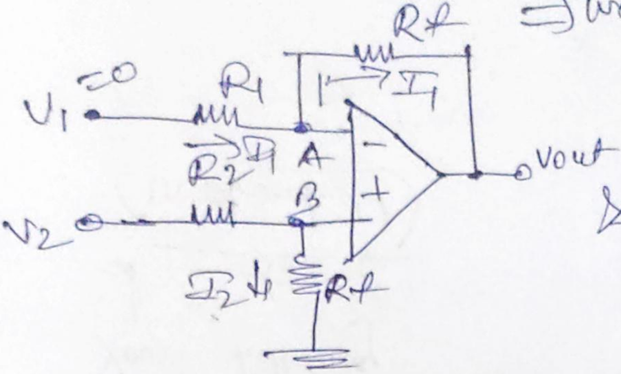
$$\boxed{A = \frac{-R_f}{R_1}}$$

(b)



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

#26> Substraction (Voltage Substraction)

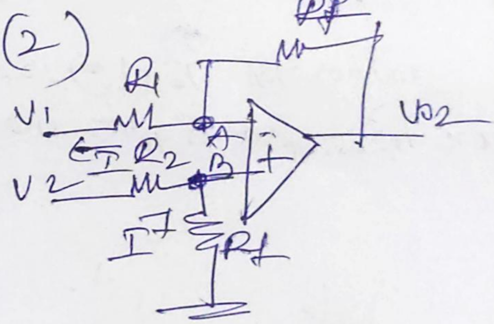


⇒ we use Superposition Theorem!
Let V_{o1} be the output with V_1 & assuming $V_2 = 0$
& V_{o2} be the output with V_2 assuming $V_1 = 0$

Now with $V_2 = 0$, the ckt acts as an inverting amplifier & output equation is $\boxed{V_{O1} = -\frac{R_f}{R_1} V_1}$ —(1)

While with $V_1 = 0$, the ckt reduces to as shown.
Let potential of node B be V_B. The potential of node A is same as B i.e $V_A = V_B$ (virtual short).
Apply voltage divider rule to the input V_2 loop

$$\boxed{V_B = \frac{R_f}{R_2+R_f} V_2} \quad -(2)$$



from figure
$$I = \frac{V_A}{R_1} = \frac{V_B}{R_1} \quad -(3)$$

Now
$$I = \frac{V_{o2} - V_A}{R_f} = \frac{V_{o2} - V_B}{R_f} \quad (4)$$

Equate (3) & (4)

$$\frac{V_B}{R_1} = \frac{V_{o2} - V_B}{R_f}$$

$$\Rightarrow V_{o2} = \frac{R_1 + R_f}{R_1} V_B$$

$$\Rightarrow \boxed{V_{o2} = \left[1 + \frac{R_f}{R_1}\right] V_B} \quad -(5)$$

substitute V_B from (2) in (5)

$$\Rightarrow V_{o2} = \left[1 + \frac{R_f}{R_1}\right]\left[\frac{R_f}{R_2+R_f}\right] V_2$$

Now using superposition theorem
$$V_o = V_{o1} + V_{o2}$$

$$\Rightarrow \boxed{V_o = -\frac{R_f}{R_1} V_1 + \left[1 + \frac{R_f}{R_1}\right]\left[\frac{R_f}{R_2+R_f}\right] V_2}$$

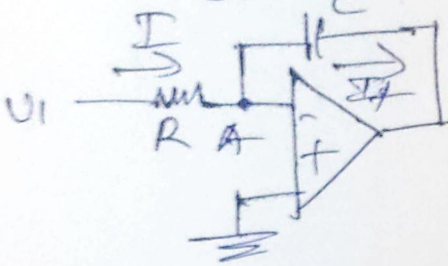
if $R_1 = R_2$

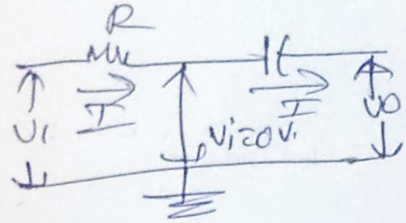
$$\boxed{V_o = \frac{R_f}{R_1}(V_2 - V_1)} \quad -(6)$$

if $R_1 = R_f$

$$\Rightarrow \boxed{V_o = V_2 - V_1} \quad -(7)$$

(7) Integrator:





Applying KCL at node A, $I = I_f$ —(1)

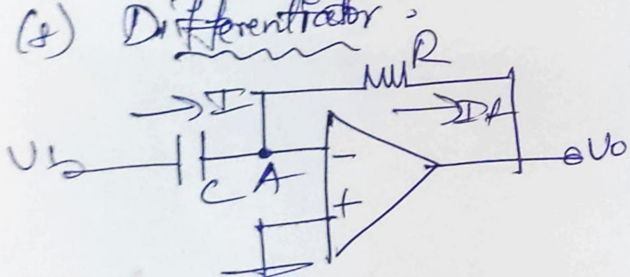
where $I = \frac{V_1 - V_A}{R}$ & $I_f = C\frac{d(V_A - V_O)}{dt}$

$V_A = 0$ due to virtual Ground →(2)

& $\frac{V_1}{R} = C\frac{d(-V_O)}{dt} \Rightarrow \boxed{\frac{dV_O}{dt} = -\frac{1}{RC}V_1}$ —(3)

$$\Rightarrow \boxed{V_{out}(t) = -\frac{1}{RC}\int_0^t V_{in}(t)\,dt} \quad -(4)$$

(8) Differentiator:



Apply KCL at node A, $I = I_f$ —(1)

$$C\frac{d(V_1 - V_A)}{dt} = \left(\frac{V_A - V_O}{R}\right) \quad -(2)$$

& $V_A = 0$ due to Virtual Ground

$$\Rightarrow C\frac{dV_1}{dt} = \frac{-V_O}{R} \quad -(3)$$

$$\Rightarrow \boxed{V_O = -RC\frac{dV_1}{dt}} \quad -(4)$$