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ASSIGNMENT - 3

BASICS OF ELECTRONICS & COMM ENGG.

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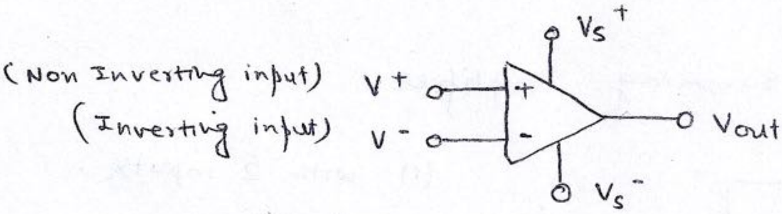
Q1. (i) <u>operational Amplifier</u>

It is a DC coupled, high gain electronic voltage amplifier with two differential inputs and a single ended output. It usually uses feedback to control its overall response characteristics.



(ii) <u>characteristics of Practical op Amp</u>

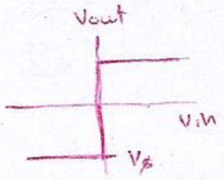
<u>Ideal op amp characteristics</u> — practically

→ infinite gain (~ 10^5 to 10^6)
→ infinite input impedance (~ MΩs)
→ zero output resistance (~ 10s of Ωs)
→ infinite bandwidth (limited by slewrate ≠ ∞)
→ No offset ie $V_{out} = 0$ when $V_{in} = 0$ (~ mVs)
→ Common mode rejection ratio = ∞ (~ 10s of dBs)
→ ∞ slew rate (~ deV/sec)

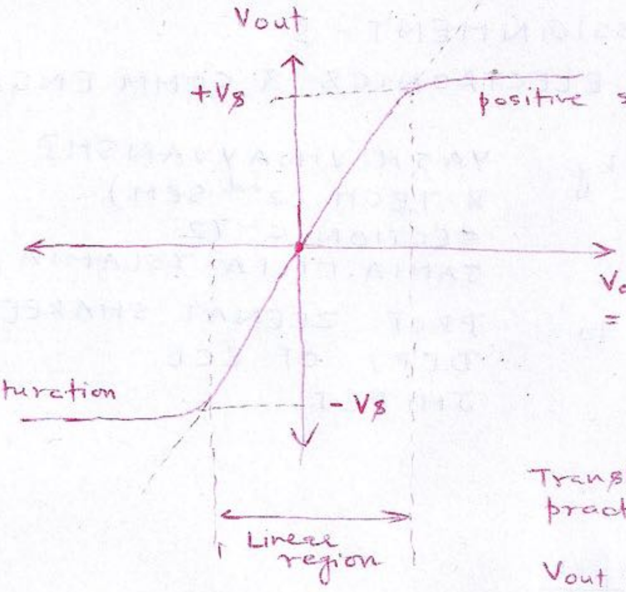
A practical op amp exhibits imperfections from ideal characters due to practical limitations as:
→ improper matching of transistors in differential stage
→ bulk and parasitic capacitance
⋮ so on.

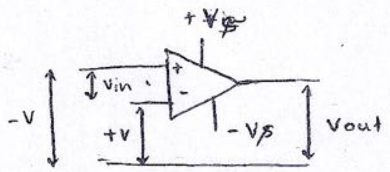
<u>voltage transfer characteristics of practical op amp</u>

The maximum output of an opamp is limited by DC supply voltages supplied to op amp. At most, output voltage excursions are limited within V_s^+, V_s^- where V_s is power supply voltage. Similarly output currents from the op amp are also limited by these saturation voltages. Between sat^h voltages, op-amp works as a linear voltage amplifier with slope given as $\frac{V_{output}}{V_{input}}$ representing open loop gain (ie when no feedback is used)



(ideal op amp)

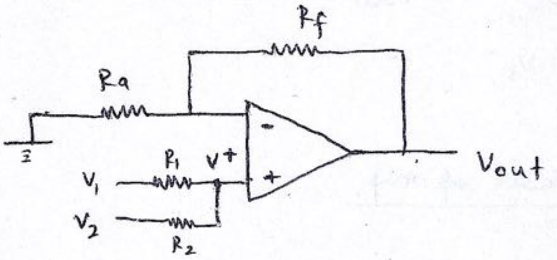




Transfer characteristics of practical op amp.

Vout : output voltage
Vd : differential voltage
V+ : non inverting input
V- : inverting input
Vs : DC source voltage/ saturation voltage

Q2. Non inverting Summing Amplifier.



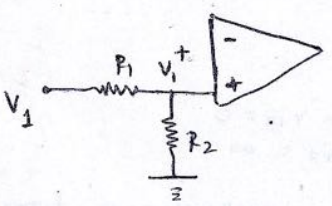
(i) with 2 inputs.

$$V_{out} = \left(1+\frac{R_f}{R_a}\right)V^+$$

[relⁿ b/w Vout & Vin for non inverting Amplifier. However due to virtual short V+ = Vin]

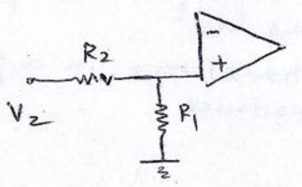
Applying superposition principle to calculate V+

effect of V_1



$$V_1^+ = \frac{R_2}{R_1+R_2}V_1 \quad \text{(voltage divider)}$$

effect of V_2



$$V_2^+ = \frac{R_1}{R_1+R_2}V_2.$$

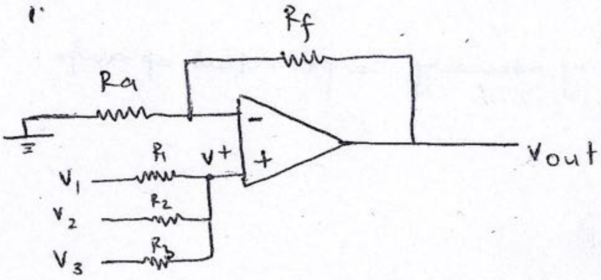
$$V^+ = V_1^+ + V_2^+$$
$$= \frac{R_2}{R_1+R_2}V_1 + \frac{R_1}{R_1+R_2}V_2$$

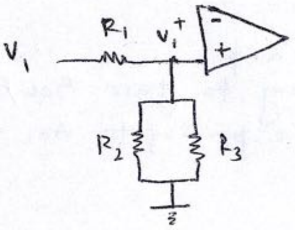
$$\therefore V_{out} = \left(1+\frac{R_f}{R_a}\right)V^+$$
$$= \left(1+\frac{R_f}{R_a}\right)\left[\frac{R_2}{R_1+R_2}V_1 + \frac{R_1 V_2}{R_1+R_2}\right]$$

if $R_1 = R_2 = R$ & $R_f = R_a$

$$V_{out} = (1+1)\left[\frac{V_1+V_2}{2}\right] = \boxed{V_1+V_2}$$

i·





(ii) If 3 inputs. (if $R_1 = R_2 = R_3 = R$)

$$V_1^+ = \frac{R_2 \parallel R_3}{R_1 + (R_2 \parallel R_3)} \times V_1 = \frac{V_1}{3}$$

$$V_2^+ = \frac{R_1 \parallel R_3}{R_2 + (R_1 \parallel R_3)} \times V_2 = \frac{V_2}{3}$$

$$V_3^+ = \frac{R_2 \parallel R_1}{R_3 + (R_2 \parallel R_1)} \times V_3 = \frac{V_3}{3}$$

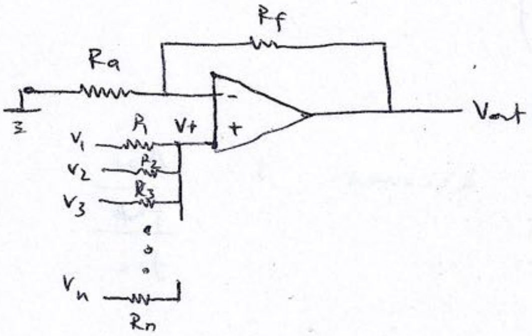
$$V^+ = V_1^+ + V_2^+ + V_3^+$$
$$= \frac{V_1 + V_2 + V_3}{3}$$

For neg. feed back (ie Non inverting Amp)

$$V_{out} = \left(1 + \frac{R_f}{R_a}\right) V^+ = \left(1 + \frac{R_f}{R_a}\right)\left(\frac{V_1 + V_2 + V_3}{3}\right)$$

if $1 + \frac{R_f}{R_a} = 3$ ~ $\boxed{V_{out} = V_1 + V_2 + V_3}$

(iii) Similar to (i) & (ii). If there a n inputs to be Added,



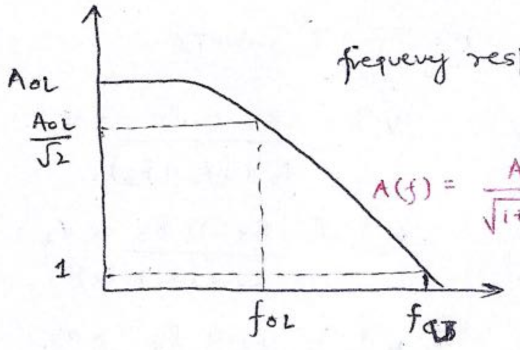
$$V_{out} = V_1 + V_2 + \dots + V_n$$
if $R_1 = R_2 = R_3 = \dots = R_n$
& $1 + \frac{R_f}{R_a} = n$

Limitations of non inverting summing amplifier.

(i) Theoretically, any no. of inputs can be added but practically no. of inputs are limited by V_s
ie $V_1 + V_2 + \dots + V_n \leq V_s$

(ii) All indivisual input voltage sources are not isolated from each other.

Q3



frequency response of internally compensated op amp

A_{OL} : Maximum open loop gain of op amp.

(3dB drop frequency) f_{OL} : cutoff freq : freq. corresponding to gain $A_{OL}/\sqrt{2}$.

f_{GB} : bandwidth (unity gain) freq : frequency corresponding to $A_{OL} = 1$

$$|A| = \frac{A_{OL}}{\sqrt{1+(f/f_{OL})^2}}$$

At $A = 1$, $f = f_{GB}$

$$1 = \frac{A_{OL}}{\sqrt{1+\left(\frac{f_{GB}}{f_{OL}}\right)^2}}$$

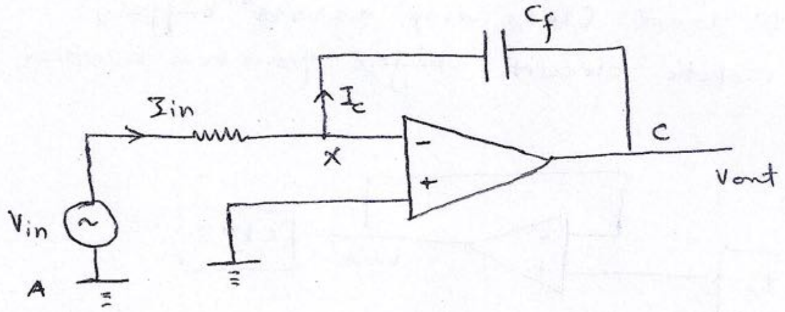
since $f_{OL} << f_{GB}$

$$\therefore 1 = \frac{A_{OL}}{\sqrt{\frac{(f_{OL})^2+(f_{GB})^2}{(f_{OL})^2}}}$$ becomes $$1 = \frac{A_{OL}}{\frac{f_{GB}}{f_{OL}}}$$

$$\therefore \boxed{f_u = A_{OL} f_{OL}}$$ proved

Q4. op-amp as an integrator.

If we use a reactive component such as capacitor with an op-amp, we can use it as integrator or differentiator



Due to virtual short, $V_x = 0$

By KCL from A to C,

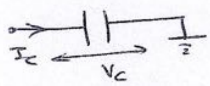
$$I_{in} = I_c.$$

$$\frac{V_{in} - 0}{R} = C_f \frac{dV_c}{dt} \quad (0 - V_{out})$$

$$\frac{V_{in}}{R} = -C_f \frac{d}{dt} V_{out}$$

$$\frac{dV_{out}}{dt} = \frac{-1}{RC_f} \times V_{in}(t)$$

(for capacitor ckt



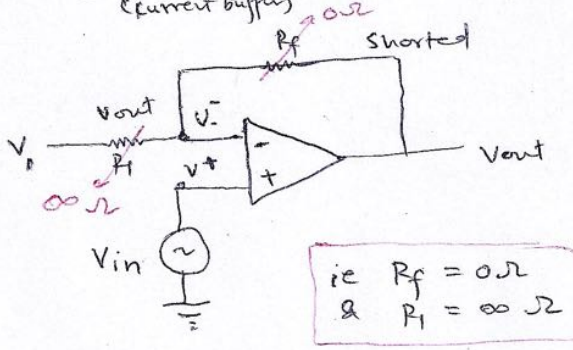
$$i_c = \frac{dQ}{dt} = C\frac{dV_c}{dt}$$
)

$$V_{out}(t) = \frac{-1}{RC_f} \int V_{in}(t)\,dt + V_{out}(0^+)$$

($V_{out}(0^+)$: Vout before integration as const of integration)

Q5. (i) voltage follower / Buffer

A buffer Amplifier is a ckt that provides electrical impedance transformation from one circuit to another with aim of preventing the signal source from being affected by currents or voltages that load is produced with. (current buffer)



ie $R_f = 0\Omega$
& $R_1 = \infty\,\Omega$

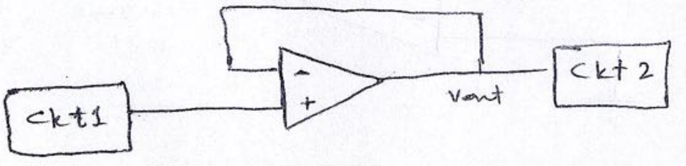
Due to virtual short b/w inverting & non inverting terminals

$$V^- = V^+$$
$$V^- = V_{in} = V_{out}.$$

∴ output voltage mirrors / follows input voltage.

(ii) Applications of voltage follower.

- → used to provide high input impedance and therefore preventing loading of source.
- → low input impedance, maximum of source voltage applied to load (less drop across buffer)
- → used to isolate circuit stages from one another.



useful if Ckt 2 has low input impedance and can load Ckt 1.

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