$R_C = 0.5\,K\Omega$

FET (Field Effect Transistor):-

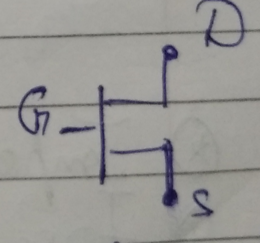
Grade (G)
Source (S)
Drain (D)

BODY (B) / Substrate

JFET (Junction FET)
MOSFET (Metal Oxide Semiconductor FET)

PMOS (P channel)
NMOS (N-channel)
CMOS (Complementary)

Current gain (α) $\rightarrow$ CB
(β) $\rightarrow$ CE



(JFET)

Voltage gain

BJT (Bipolar) Current control, Current Gain, amplifica.

FET (Unipolar) Voltage Cont., Voltage, Variable Voltage Regulator.

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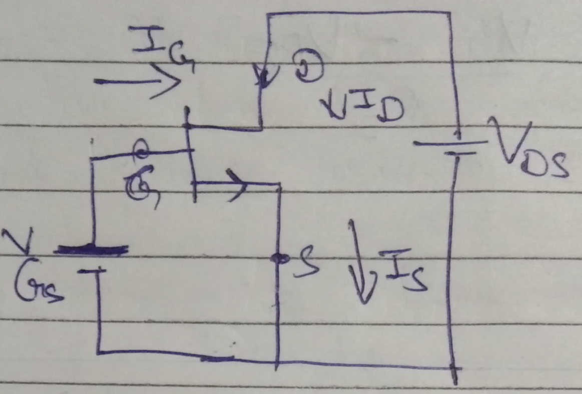
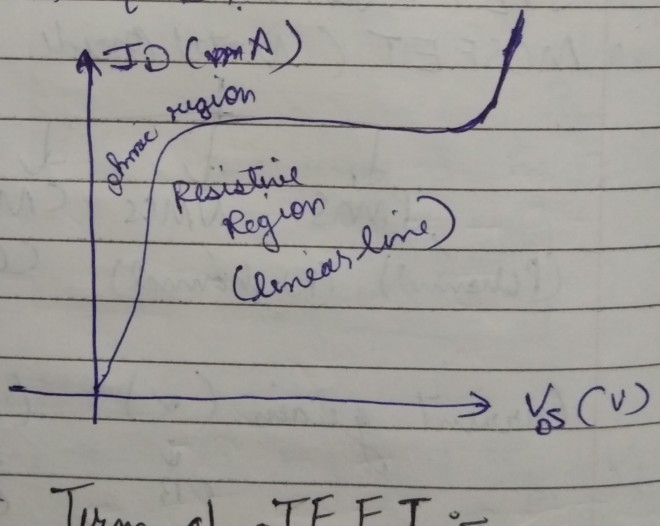


Pinch off → is condition when channel formed.

Threshold voltage :- minimum amount of voltage required for conduction to start in FET.



* Important Term of JFET :-
1. I_{DSS} = Short gate drain current.
2. V_p (Pinch off voltage)
3. Gate source cut off voltage $V_{GS\,(off)}$

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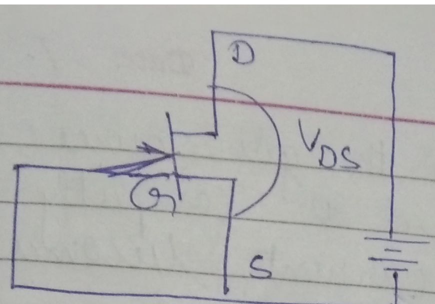
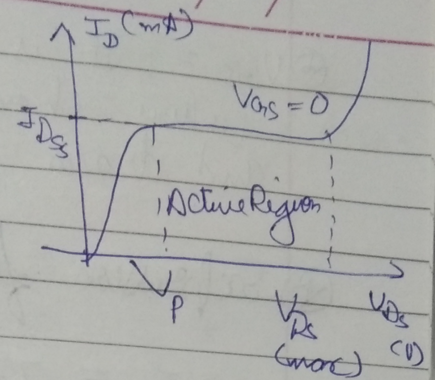
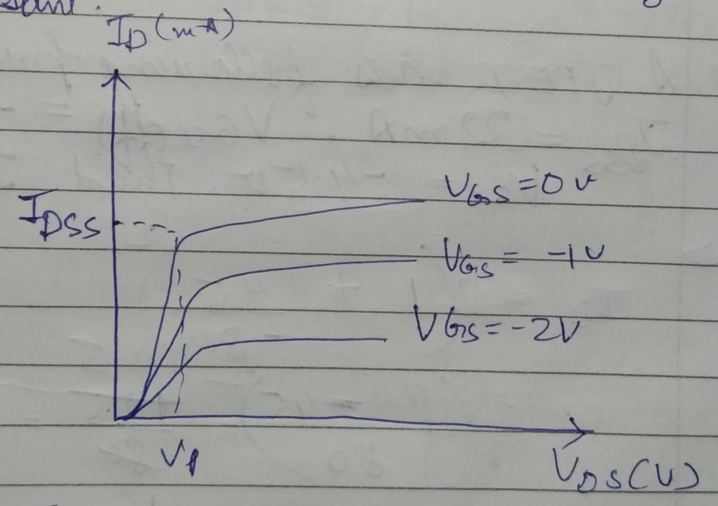
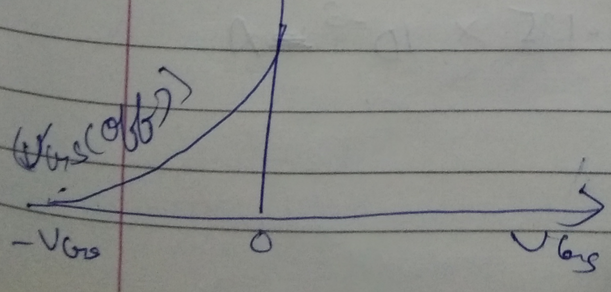




* It is a drain current with source short circuit to gate ($V_{GS} = 0$) & V_{DS} = pinch off voltage, sometimes its called zero biased current.

* <u>Pinch off</u> ⇒ It is defined as the min V_P at which I_D essentially becomes constant.





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* V_{GS} = It is the gate source voltage where channel is completly cut off and drain current becomes zero.

* Expression for drain current for JFET

$$I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_{GS(off)}}\right]^2$$

I_D = drain current at given V_{GS}

I_{DSS} = shorted gate drain current

V_{GS} = gate source voltage

$V_{GS(off)}$ = gate source cut off voltage

Q→ A JFET has following parameter
$I_{DSS} = 32\,mA$. $V_{GS(off)} = -8V$
$V_{GS} = -4.5V$ Find I_D.

⇒

$$I_D = 32\left(1 + \frac{4.5}{-8.0}\right)^2$$

$$= \left(\frac{8.0 - 4.5}{8.0}\right)^2 = \frac{\cancel{12.5}^{\,25}}{\cancel{8.0}_{\,16}} = \frac{\cancel{3.5}}{16} \times 32$$

$$= 6.125 \times 10^{-3}\,A$$

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Ques> A JFET to be used as an amplifier having following para.

$V_{GS(off)} = V_P = -25V.$

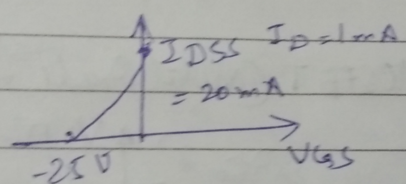
$I_{DSS} = 20mA$

Plot trans-conductance curve.

⇒ Assume $= I_D = 1mA$

$$I_D = 20 \times 10^{-3} \left[1 + \frac{V_{GS}}{25}\right]^2$$

$$\left(\sqrt{\frac{1}{20}} - 1\right)25 = V_{GS} = -19.4V.$$



Q→ A JFET has drain current of 5mA. If $I_{DSS} = 10mA$, $V_{GS(off)} = -6V$. Find value of ① V_{GS}, ② V_P, ③ Plot curve.

⇒

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(off)}}\right)^2$$

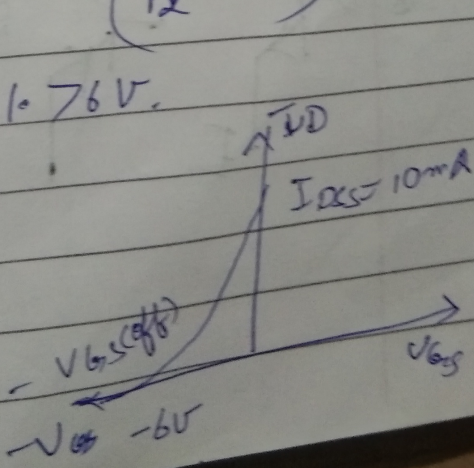
$$5 \times \cancel{10^{-3}} = 10 \times \cancel{10^{-3}} \left(1 + \frac{V_{GS}}{6}\right)^2$$

$$V_{GS} = \cancel{-1.76} \left(\sqrt{\frac{1}{2}} - 1\right)6$$

$$= -1.76V.$$

$V_P = -~~V_{GS(off)}~~$

$= 6V.$



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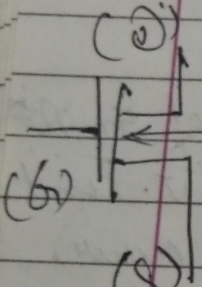
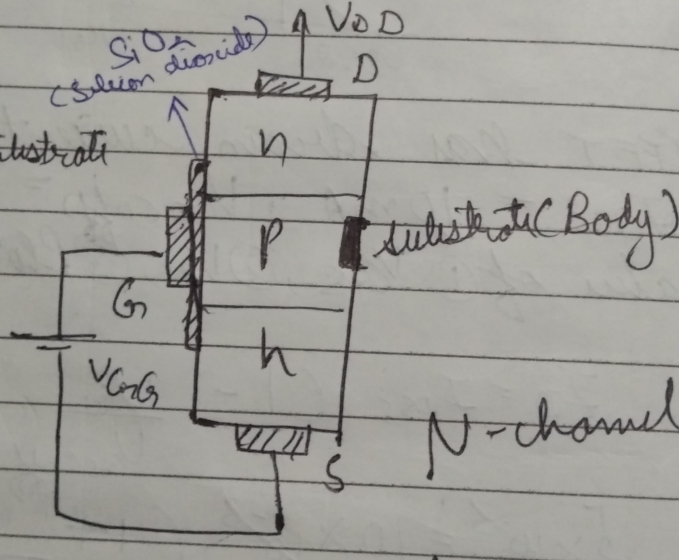
MOSFET

E-MOSFET (Enhancement Type)
- N channel
- P channel

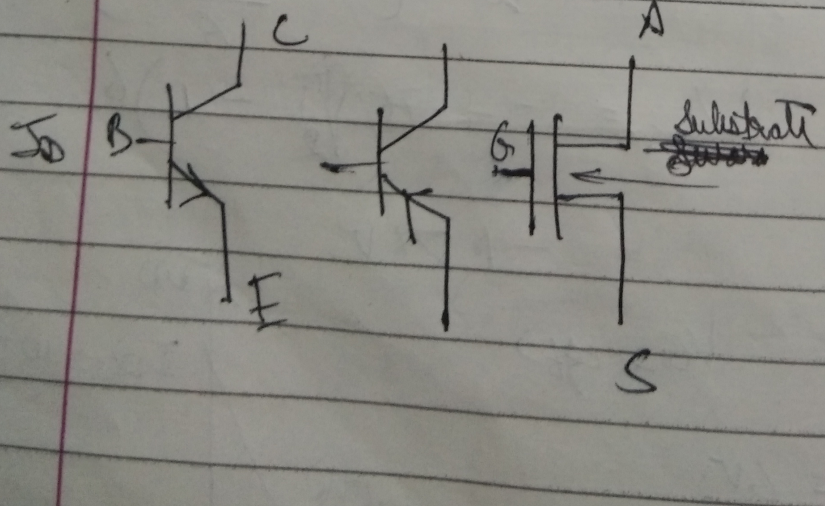
D MOSFET (Depletion type)
- N channel
- P-channel

MOSFET (Metal Oxide Semiconductor FET)





N-channel



channel

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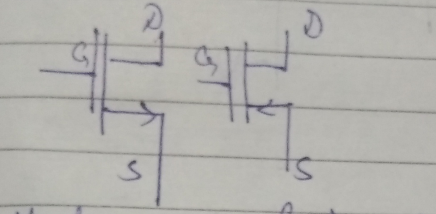
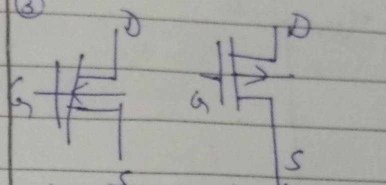
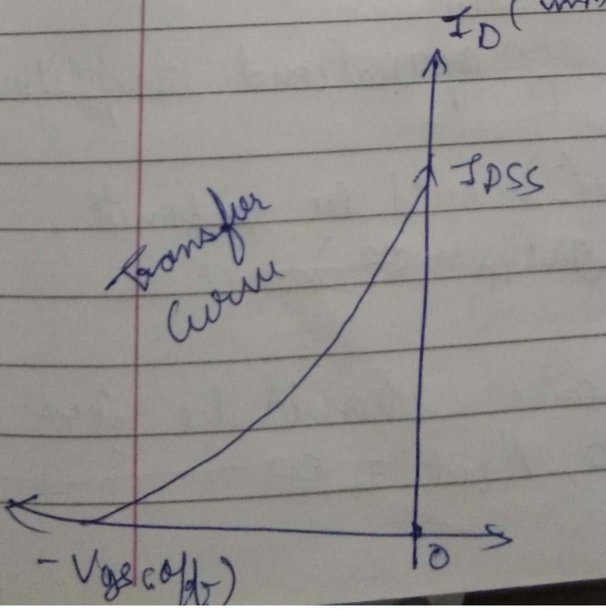
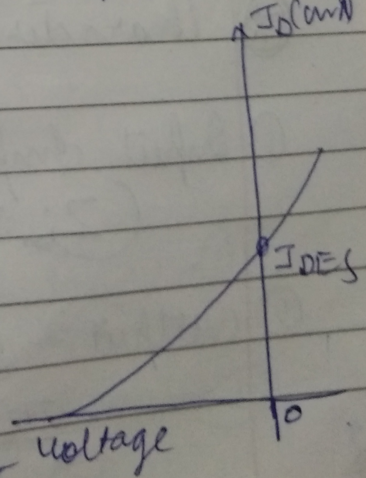
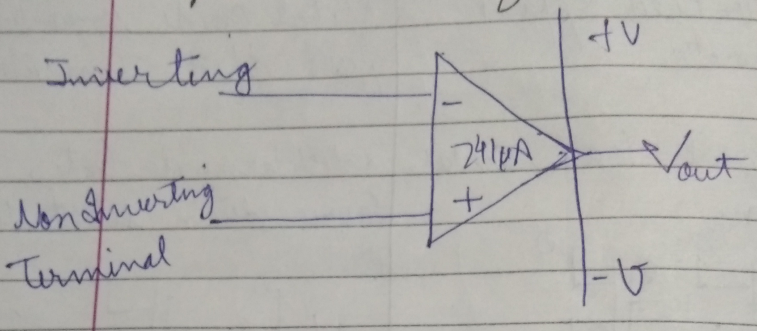
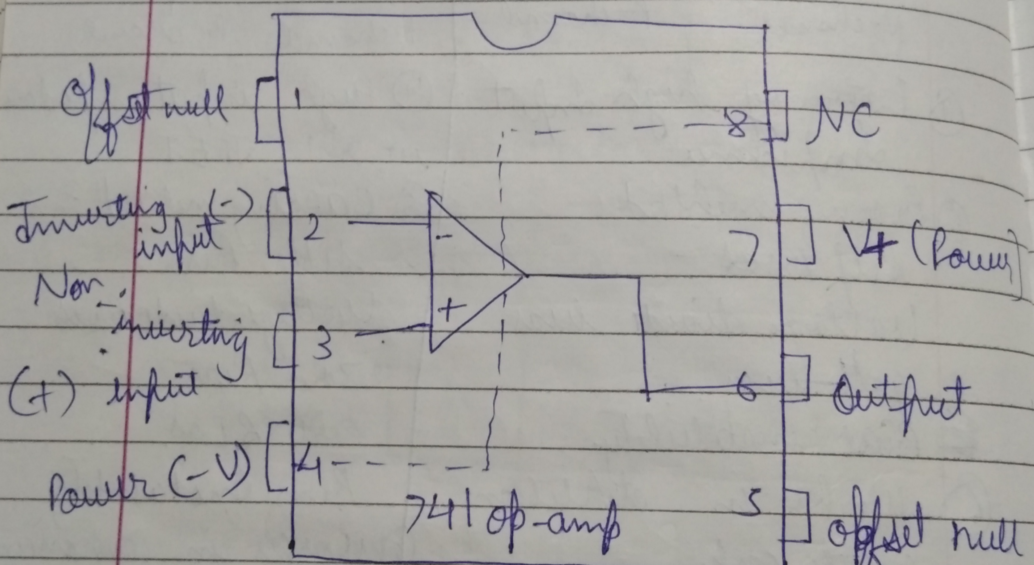
JFET	MOSFET
Junction Field Effect Transistor	Metal Oxide semiconductor field effect Transistor.
② 3 terminals Gate, Source, drain.	② 4 terminal Gate, Source, drain, substrate
③ 	③ 
④ Extremely high Input Impedance	④ High input impedance w.r.t JFET
⑤ Biasing method Self Bias Voltage divider bias gate bias Bias instability.	⑤ Biasing method :- Self Bias Voltage divider Bias Zero Bias Gate Bias. Bias Instability
⑥ Works in depletion mode only.	⑥ Works in enhancement & depletion mode.
	

Operational Amplifier (op-amp)





Characteristic of Ideal operational Amplifier

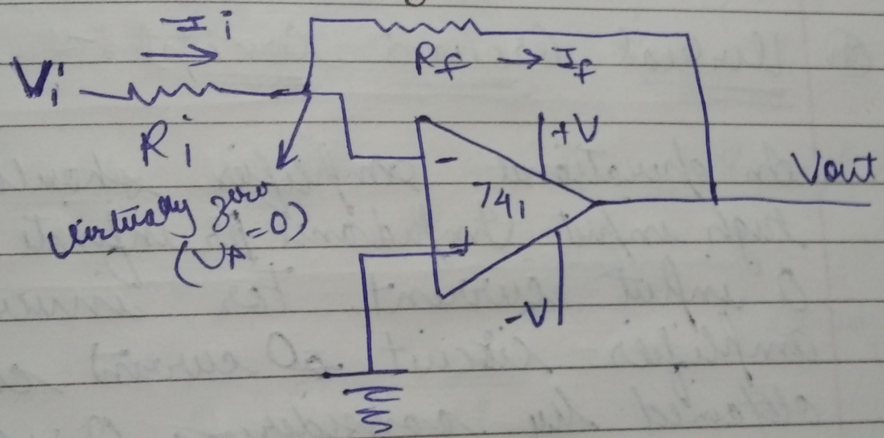
① Input Impedance (Z) should be infinite.
($Z_{in} = \infty$ or $R_{in} = \infty$)

② Output Impedance should be zero
$Z_{out} = 0$, $R_{out} = \infty$

Date: / /

(3) Open loop gain should be infinite.
$$G = \frac{V_{out}}{V_{in}} = \infty$$
(4) Input offset voltage should be ∞.
(5) Noise should be zero.
(6) Infinite bandwidth.
(7) ∞ Slew rate.
(8) ∞ CMRR (Common Mode Rejection Ratio)
(9) 0 phase shift] x
(10) Infinite power supply Rejection Ratio.
(11) 0 input current for ∞ input impedance

Op-amp Inverting Amplifier :-



R_i = input resistance
R_f = feedback resistance
V_i = i/p voltage
V_{out} = output voltage.

$$I_i = \frac{V_i - V_A}{R_i} = \frac{V_i}{R_i} \quad -(1)$$

$$I_f = \frac{V_A - V_{out}}{R_f} = \frac{-V_{out}}{R_f} \quad -(2)$$

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from ① & ②
apply KCL

$$I_i = I_f$$

$$\frac{V_i}{R_i} = \frac{-V_{out}}{R_f}$$

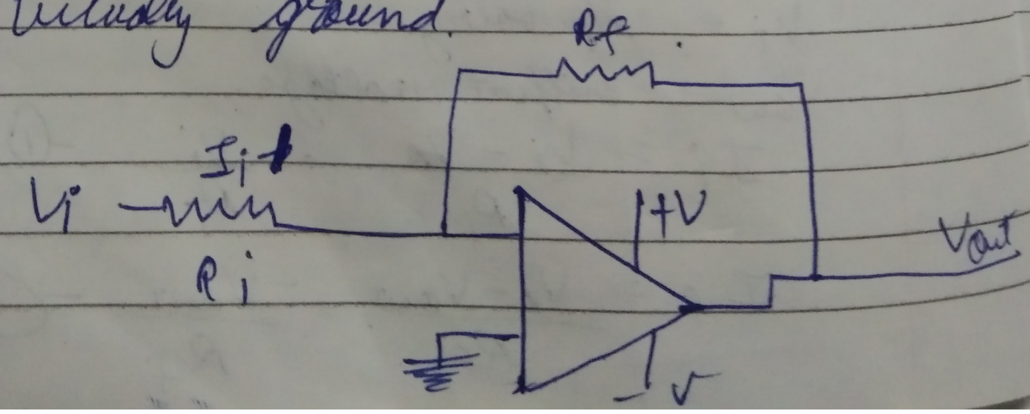
$$\frac{V_{out}}{V_{in}} = \frac{-R_f}{R_i}$$

$$\boxed{A_{CL} = \frac{V_{out}}{V_{in}} = \frac{-R_f}{R_i}}$$

Close loop voltage Gain

④ Virtual Ground Concept :-

An operational amplifier should have high input Impedance or infinite, and 0 input current. For inverting amplifier circuit 0 current can be obtained by considering 0 voltage from feedback point w.r.t. the ground or this point is called virtually ground.



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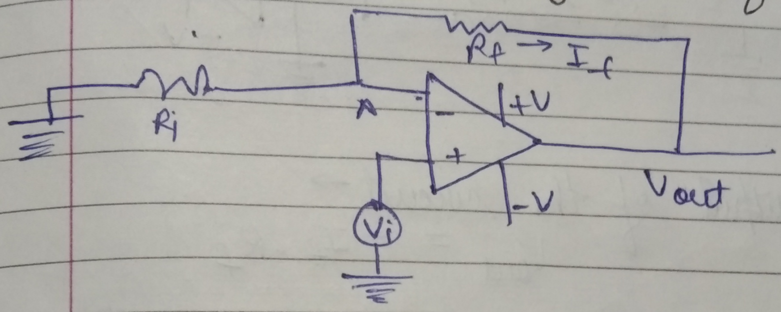
In circuit of non inverting amplifier V_A is having zero voltage, this is called virtual (non grounded but considered) voltage.

④ Op-amp non-inverting amplifier:-



Voltage across R_i $= V_i - 0 = V_i$

Voltage across R_f $= V_{out} - V_i$

Current by R_i = Current through R_f

$$\frac{V_i}{R_i} = \frac{V_{out} - V_i}{R_f} \quad \left[\text{Divide by } V_i\right]$$

$$\frac{1}{R_i} = \frac{\frac{V_{out}}{V_i} - 1}{R_f}$$

$$\frac{R_f}{R_i} + 1 = \frac{V_{out}}{V_{in}} = A_{CL}$$

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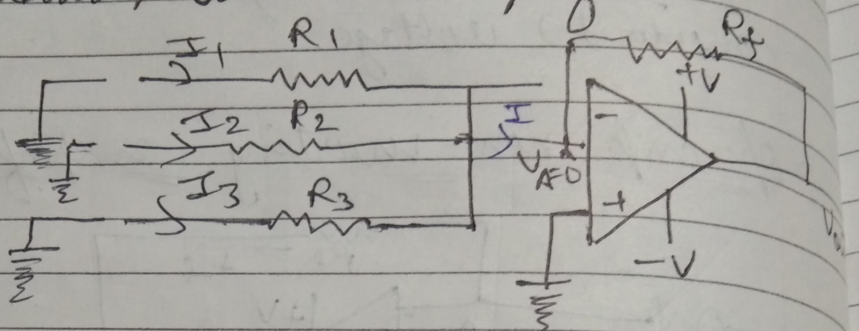
Applications of Op-amp :-

1) Adder/ Summer Amplifier :-



Output of the circuit →

$$V_{out} = -I_f \cdot R_f$$

$$I_f = I = I_1 + I_2 + I_3$$

$$V_{out} = -(I_1 + I_2 + I_3) R_f$$

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

Let us assume

$$R_1 = R_2 = R_3 = R$$

$$V_{out} = -\frac{R_f}{R}(V_1 + V_2 + V_3)$$

Ques → What will be output expression for op-amp if treated as summing amplifier & $R_1 = R_2 = R_3 = 3K\Omega$, $R_f = 1K\Omega$ Design circuit ?

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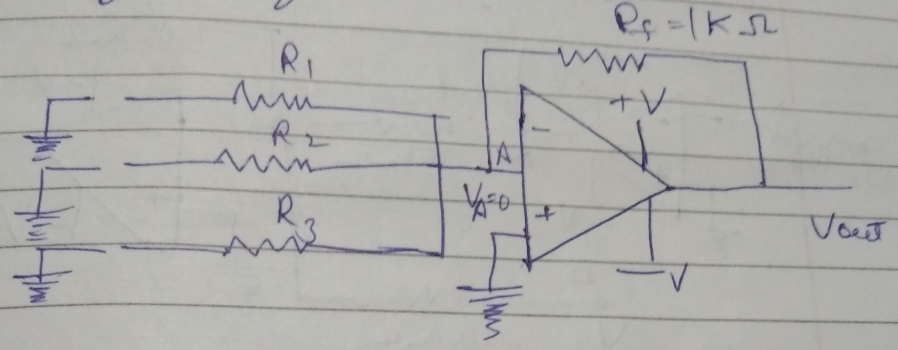
→ As $V_{out} = \frac{-R_f}{R}(V_1 + V_2 + V_3)$

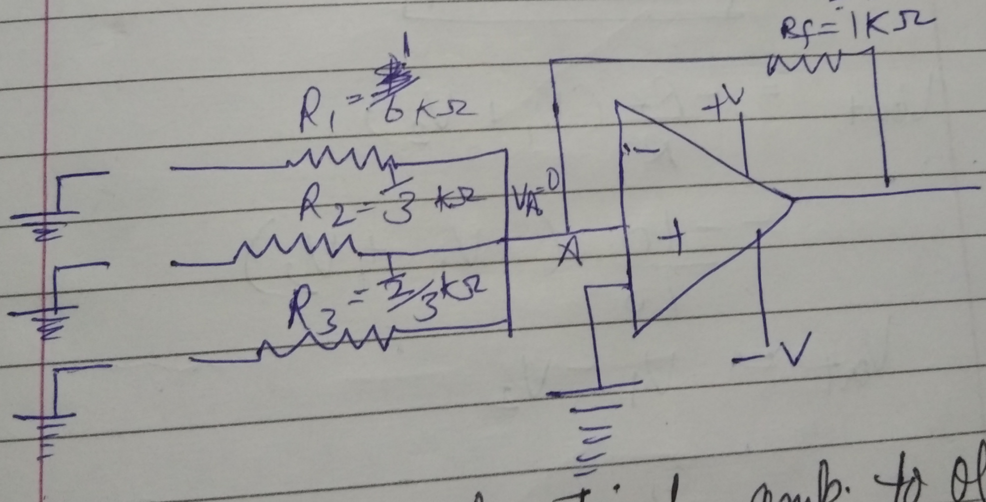
$= \frac{-1}{3}(V_1 + V_2 + V_3)$

Average Amplifier:-



Q→ Design a circuit which provides following output $V_{out} = +(6V_1 + 2V_2 + 4V_3)$

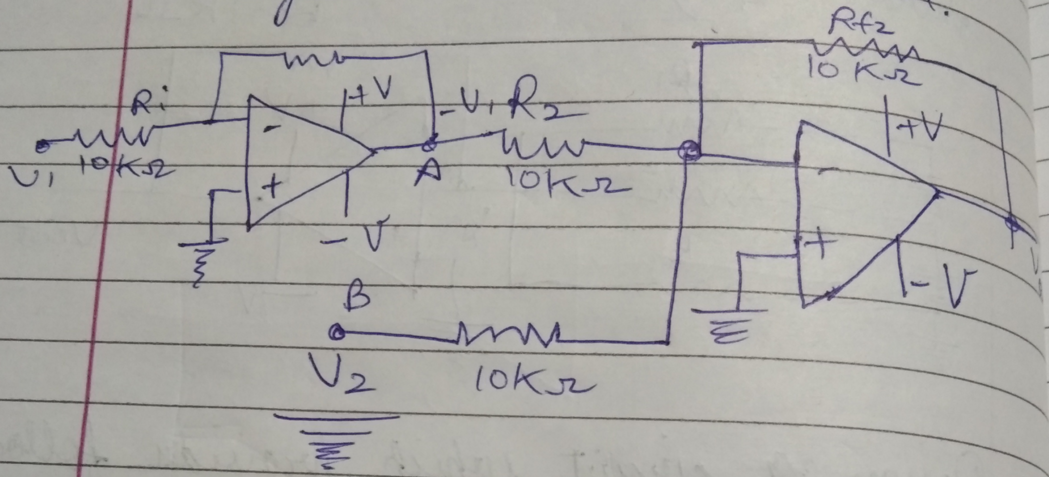
$$V_{out} = +6\left(\frac{V_1}{6} + \frac{V_2}{3} + \frac{V_3}{3/2}\right)$$



Q→ Design an operational amp. to obtain exp:?

$V_{out} = -(2V_A + 3V_B + V_C)$

2. As Substractor = A summing amplifier can be used to provide output voltage i.e. circuit equal to diff. of 2 voltages. Such circuit as Substractor.



$$\frac{V_A}{V_1} = \frac{-R_f}{R_i} = \frac{-10}{10}$$

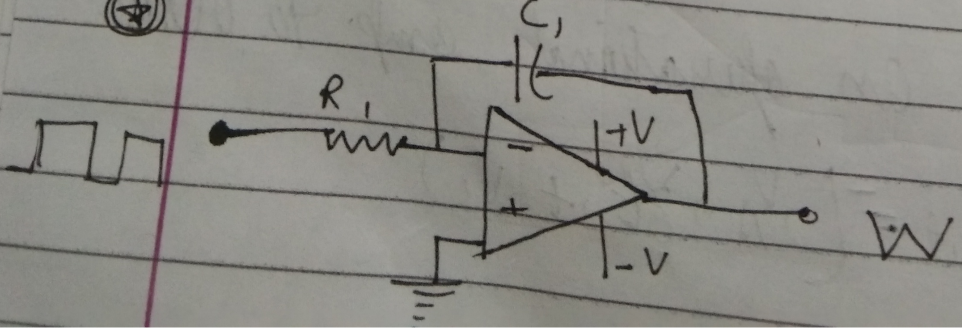
$$\boxed{V_{out} = -V_1}$$

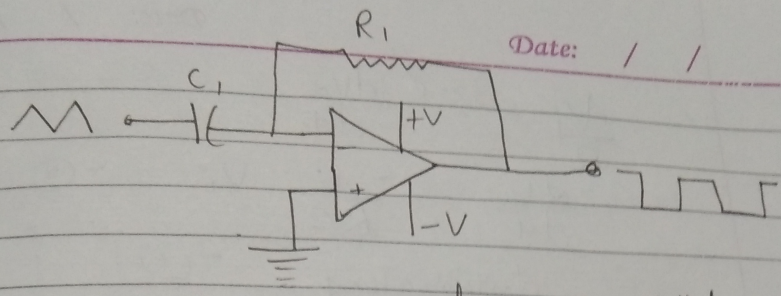
$$V_{out} = -\frac{R_f}{R}(V_1 + V_2)$$

$$= -\frac{10}{10}(-V_1 + V_2)$$

$$V_{out} = V_1 - V_2$$

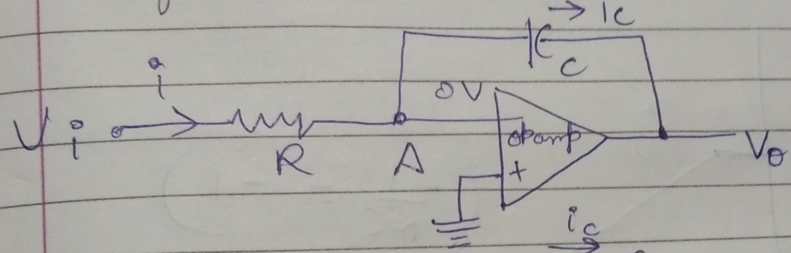
(4)

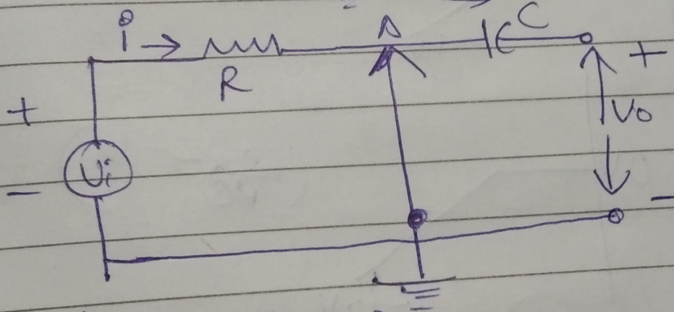




op-amp differentiator

Integrator Derivation:-





As $i = \frac{V_i - 0}{R}$

$= \frac{V_i}{R}$

$V_c = 0 - V_0 = -V_0$

$i_c = \frac{C\,dV_c}{dt} = -C\frac{dV_0}{dt}$

Applying Kirchhoff's law

$i = i_c$

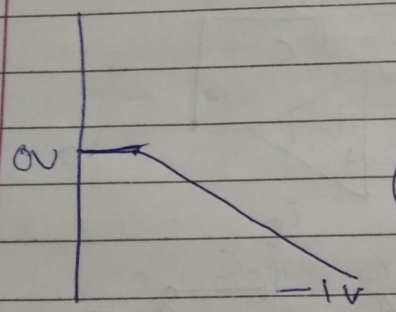
Date: / /

$$\frac{V_i}{R} = \frac{-C\, dV_o}{dt}$$

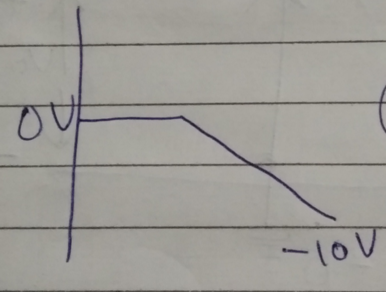
$$\frac{dV_o}{dt} = \frac{-1}{RC} V_i \quad -(1)$$

Integrating $-(1)$

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

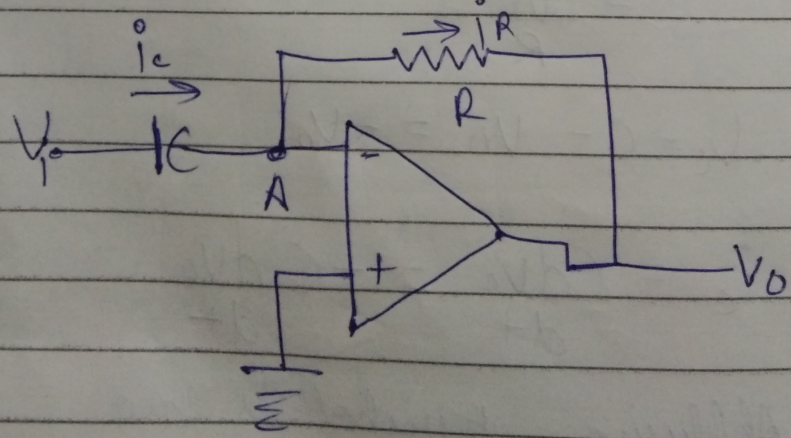


$$\left(\frac{-1}{RC} = -1\right)$$



$$\left(\frac{-1}{RC} = -6\right)$$

⑤ Op-amp Differentiator :-



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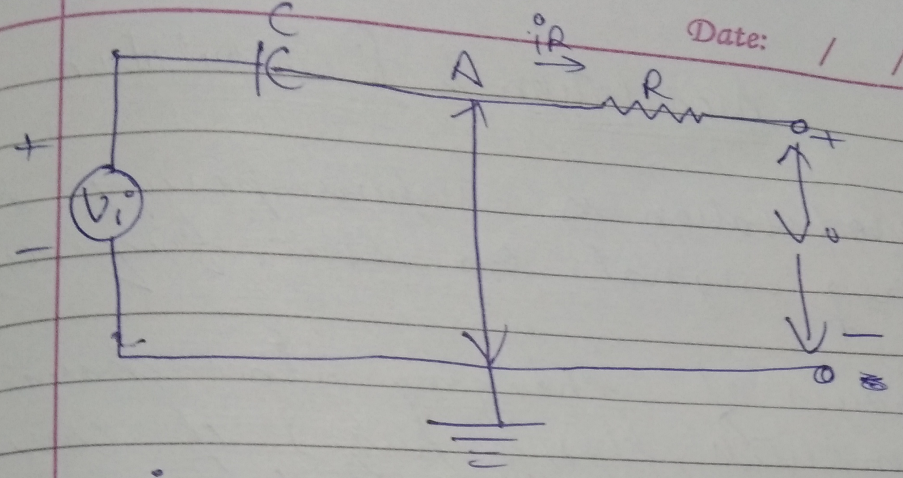


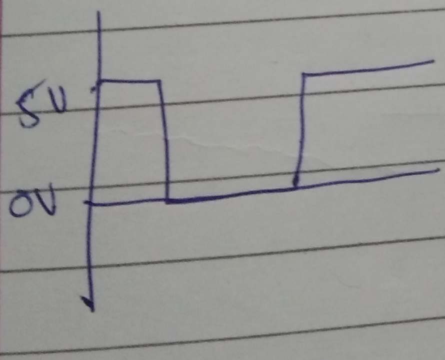
$$i_R = \frac{0 - V_o}{R} = \frac{-V_o}{R} \quad \& \quad V_c = V_i - 0 = V_i$$

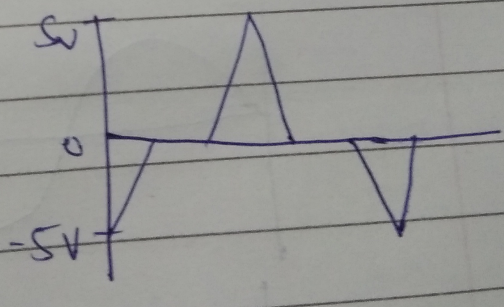
$$i_c = C\frac{dV_c}{dt} = C\frac{dV_i}{dt}$$

After K.C.L :-

$$-\frac{V_o}{R} = C\frac{dV_i}{dt} \qquad (\because i_R = i_c)$$

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





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Modulation & Demodulation

modulation is superimposing hig freq. signal on low freq. signal

Process of changing some characteristic (amplitude, phase or freq.) of carrier wave in accordance with intensity of signal is modulation.

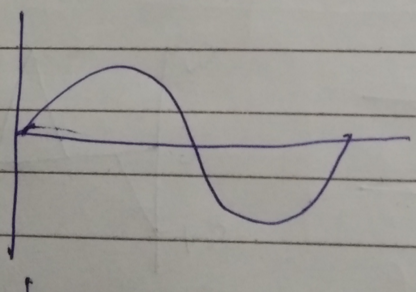
① Reduce height of antenna

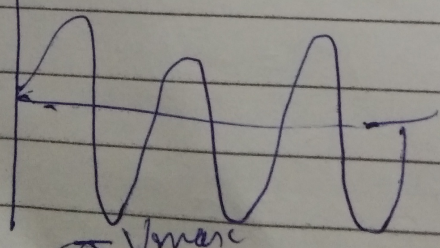
$$\lambda = \frac{v}{\nu} = \frac{3 \times 10^8}{\text{freq. (Hz)}} \text{ metres.}$$

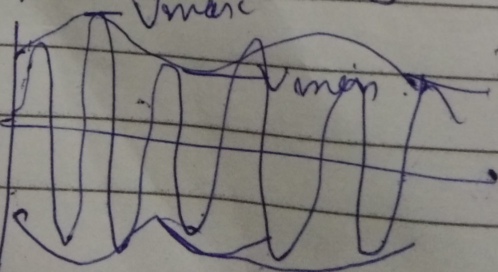
② Operating range :-

③ Wireless communication.

① Amplitude Modulation :-







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m = modulation index

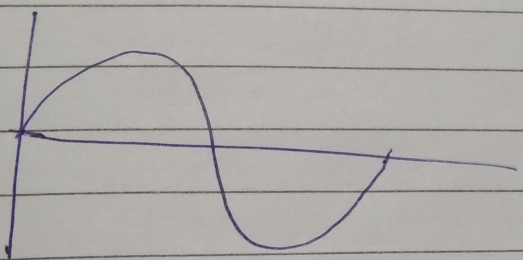
$$= \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

$m = 1$

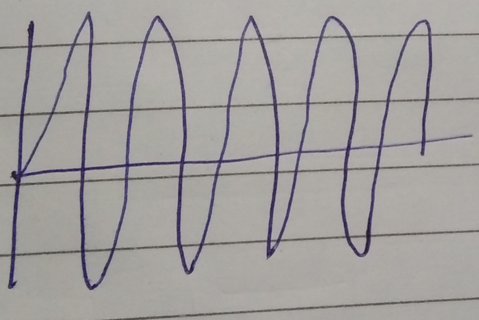
$m > 0$ over modulate

$m < 1 - 0.5$ } No modulation.

Frequency Modulation :-



Signal



Carrier