CIOT

ELECTRONICS

OPAMP

for 4TH SEM.

- The Last class - Log amplifier & Anti log amplifier .... then - i)
- ii) CMRR, Slew Rate, frequency - Response of the OPAMP

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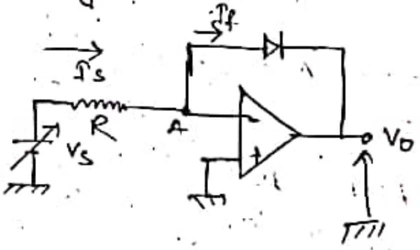
8. Log Amplifier :

for OPAMP log Amplifier O/p is proportional to the Log of the i/p voltage.



Since there is a virtual ground at the point A, so same current passes through R and diode,

$I_s = I_f$

$\Rightarrow \frac{V_s - 0}{R} = I_0\left(e^{\frac{eV}{\eta KT}} - 1\right)$

$\approx I_0 e^{\frac{eV}{\eta KT}}$

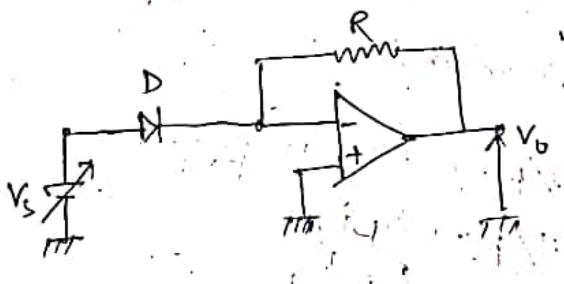
or, $V_0 = -V_f = -\frac{\eta KT}{e} \ln \frac{V_s}{I_0 R}$

- I_0 = reverse saturation current.

$\eta = 1$ for Ge
$= 2$ for Si
} diode.

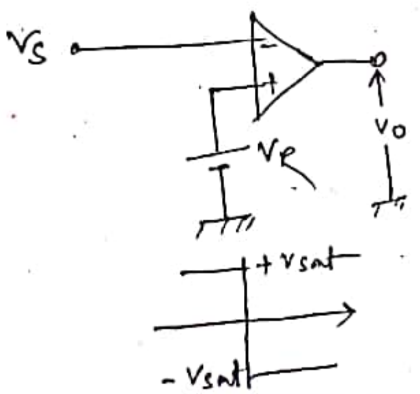
output ∝ log (input). This device working within wide range of I/p voltages.

Antilog Amplifier :



In log amplifier with we re arranged R and D position, we can get antilog Amplifier.

9. voltage Comparator : voltage comparator can comparate two voltages. OPAMP comparators can compares I/p signal V_s with a reference voltage V_R.



* As, $V_s < V_R$, O/P → V_o goes to maximum positive saturation +Vsat.

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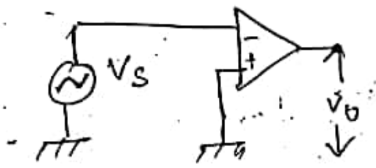
∴ as V_s cross V_R i.e. $V_s > V_R$, the OPAMP o/p switches to the negative saturation value ($-V_{sat}$). Thus by looking at the output voltages we can instantly identify whether the voltage V_s is greater than or less than V_R.

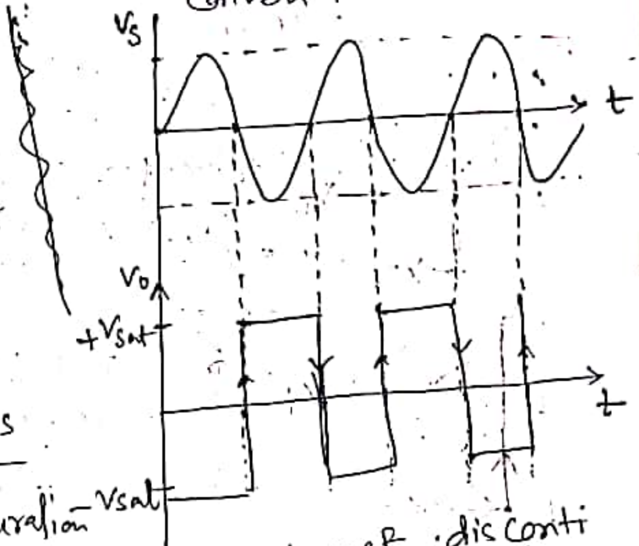
10.

• Zero-Crossing detector

The comparator can be used to generate a symmetric square waves form. sine waves by just taking $V_R = 0$. and choosing V_s as a sinusoidal voltage



Zero crossing detector
Convert ∿ → ⊓⊔



∴ when V_s passes through the +ve values the V_o is driven into the negative saturation. $-V_{sat}$, when V_s passes through '0' towards negative values the output V_o is driven to positive saturation $+V_{sat}$. Thus if $V_R = 0$, the O/P changes almost discontinuously from one state to the other every time the input signal passes through zero. For this such a configuration is called a zero crossing detector. it is also used to convert a sinusoidal waveform into a square waveform.

Maximum value = $+V_e\ V_{sat}$

Minimum " = $-V_e\ V_{sat}$

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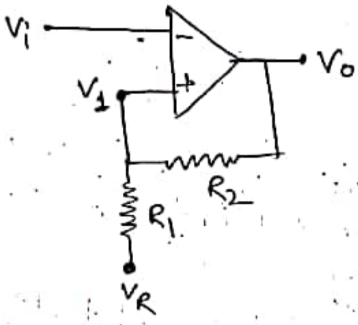
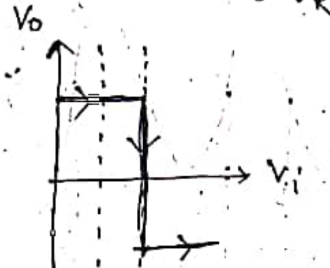
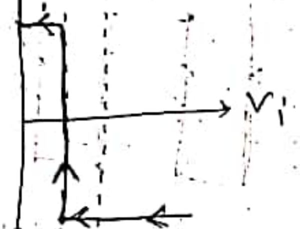
11. **Schmitt trigger :** A comparator uses positive or regenerative feedback and exhibits the phenomenon of hysterisis called a regenerative comparator or Schimitt trigger.



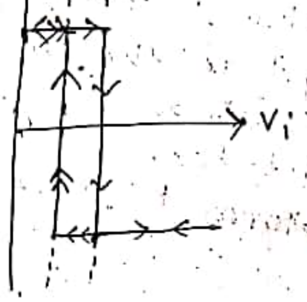
- Schmitt trigger using OPAMP
  V_R = Reference voltage.
  v_i = input voltage.
- v_i → applied inverting terminal
- V_R → " " Non "



transfer characteristics for increasing v_i



transfer characteristics for decreasing v_i



Complete transfer characteristics showing hysteresis.

- when, $v_i < v_1$ the output v_o goes to the positive saturation level $+V_{sat}$. then using super-position principle we get;

$$v_1 = \frac{R_2 V_R}{R_1 + R_2} + \frac{R_1 V_{sat}}{R_1 + R_2} = V_1 \text{ (say)}$$

→ v_i now increased but v_o = const at $+V_{sat}$ until $v_1 = V_1$, $v_i = V_1$

- At critical or threshold, critical or triggering voltage, the o/p regeneratively switches to $V_o = -V_{sat}$

$V_0 = -V_{sat}$ and remains at that value untill $v_i > V_1$. for the voltage at the non inverting terminal for $v_i > V_1$ is given by,

$$V_1 = \frac{R_2 V_R}{R_1 + R_2} - \frac{R_1 V_{sat}}{R_1 + R_2} = V_2 \text{ (Say)}$$

- If the voltage v_i is now decreased the o/p remains at $-V_{sat}$ (and $V_1 = V_2$), at this voltage o/p regeneratively switches to $+V_{sat}$.

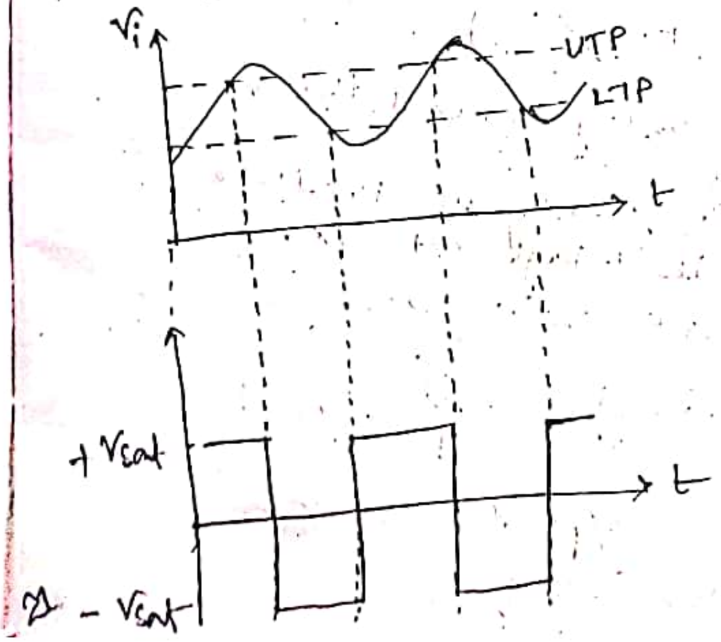
So, the ckt. triggers at different voltages depending on wheather the signal is increasing or decreasing, the ckt exhibits hysterisis. Two I/P voltages at which the o/p voltages are changed called trip points.

V_1 is the upper trip points (UTP)
V_2 is the Lower " " (LTP)

— The differences between two trip points are called hysterisis. V_H. So,

$$V_H = V_1 - V_2 = \frac{2R_1}{R_1 + R_2} V_{sat}$$

⇒ Schmitt trigger produces assymetric square wave forms from an arbitary input signal.



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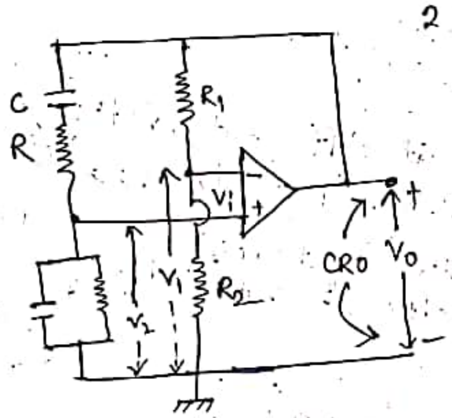
• Schmitt trigger have remain of its two stable states indefinitely. It changes the state when a triggering signal is applied, thus this Schmitt trigger ckt also known as the bistable Multivibrator

• **Wien bridge Oscillator using OPAMP:**



2 RC combination and the Resistor R_1 and R_2 forms four arms of the wien bridge.

• It is a RC Oscillator mainly used to produce AF signal.

• phase shift = 360°/0°

• Barkhausen criterion valid $\beta A = 1$

Now,

$$v_2 = \frac{V_o}{\left(R+\frac{1}{j\omega C}\right) + \frac{R\cdot\frac{1}{j\omega C}}{\left(R+\frac{1}{j\omega C}\right)}} \times \frac{R\cdot\frac{1}{j\omega C}}{\left(R+\frac{1}{j\omega C}\right)}$$

or,

$$\frac{v_2}{V_o} = \frac{\frac{R}{(1+j\omega CR)}}{\frac{1+j\omega CR}{j\omega C} + \frac{R}{1+j\omega CR}}$$

$$\Rightarrow \text{or, } \frac{V_o}{V_2} = 1 + \frac{(1+j\omega CR)^2}{j\omega CR}$$

$$= 3 + j\left(\omega CR - \frac{1}{\omega CR}\right)$$

So, v_2 may lead over or lag behind the v_o depending on the frequency ω, produce R-C combinationable lead-lag network, v_2 will be the phase with v_o at a fre. given by ω

$$\Rightarrow \omega CR = \frac{1}{\omega CR} \Rightarrow \omega = \frac{1}{CR}, \Rightarrow \boxed{f = \frac{1}{2\pi CR}}$$

23 Now, $\frac{v_2}{v_o} = \frac{1}{3}$ So, ⅓ of the o/p, feedback to the input. 23

$$v_1 = \frac{V_0 R_2}{R_1 + R_2}$$

$$v_i = v_2 - v_1$$

Now, if the bridge is balanced $v_i = 0$. then, $v_1 = v_2$

$$\frac{v_1}{V_0} = \frac{V_2}{V_0} = \frac{1}{3}$$

Now, for $v_i \neq 0$, $\frac{v_1}{V_0} = \frac{R_2}{R_1 + R_2} = 1/3 - 1/\delta$

[δ is a no. greater than 3]

So, the feedback ratio; $\beta = \frac{v_i}{V_0} = \frac{v_2 - v_1}{V_0} = 1/\delta$.

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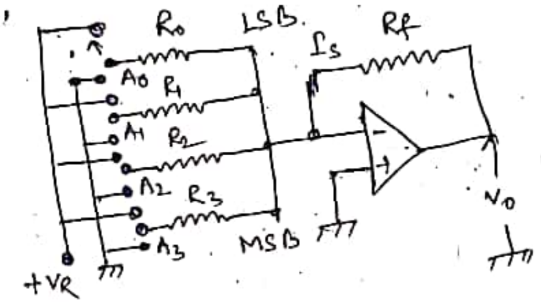
Resistive Network :

- Digital to Analog Converter :

A device that produces an analog output voltage from a given a given digital input is called a digital to analong [D/A] converter.

- Weighted Resistor (D/A)



ckt diagram for a four bit parallel D/A converter, which convert a 4 bit parallel digit word $A_3A_2A_0A_1$ to an analog voltage proportional to the binary number represented by the digit word. When any one of the digit is i.e. 'A' is 1, the corresponding i/p is connected to the V_R, when 'A' is '0' connected to the ground. the resistance's choosen as,

$$R_0 = R/2^0 = R$$

$$R_1 = R/2^1 = R/2$$

$$R_2 = R/2^2 = R/4$$

$$R_3 = R/2^3 = R/8$$

R can be choose according to the impedence level of the Network

$$V_0 = -R_f \cdot I_s$$

$$= -R_f\left[\frac{V_R}{R_3}A_3 + \frac{V_R}{R_2}A_2 + \frac{V_R}{R_1}A_1 + \frac{V_R}{R_0}A_0\right]$$

$$= -\frac{V_R R_f}{R}\left[2^3 A_3 + 2^2 A_2 + 2^1 A_1 + 2^0 A_0\right]$$

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--- $A_i = 1$ V_R · connected
= 0 '0' Gnd "

So, the o/p is proportional to the numerical value of the binary No. $A_3A_2A_1A_0$. ~~to that numerical decimal value~~

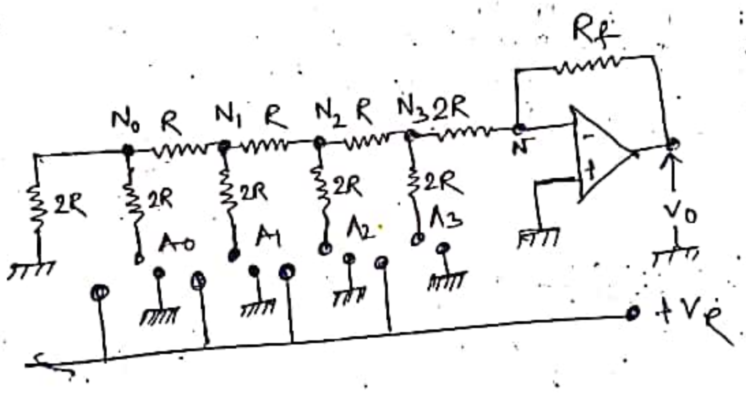
- The 4 bit converter can be easily extended to more bits simply, by adding more weighted resistors.

<u>disadvantage</u>:

i) fabricate much amount of Resistors within precision in IC form is problamable.

ii) value drifted with changing temperature.

R-2R Ladder D/A Converter:



$$V_0 = -\frac{R_f}{3R}\cdot\frac{V_R}{2^4}\left[2^3 A_3 + 2^2 A_2 + 2^1 A_1 + 2^0 A_0\right]$$

To explain the operation of the circuit let all the switches are connected to the grond except A0. The resulting resistive portion of the circuit is calcalculated by applying the Theverin theory to the left of the Node. thus the circuit becoms simplified.

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Apply Thevenin theory to left of the nodes N_1, N_2, N_3

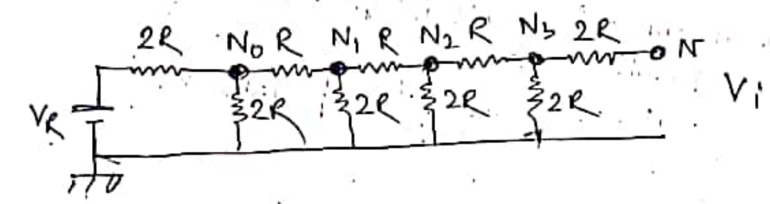
The equivalent voltage form $V_R/16$ in series with 3R

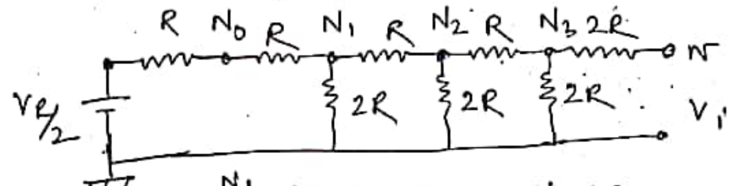
if we connect A_0 to V_R, all other to zero.

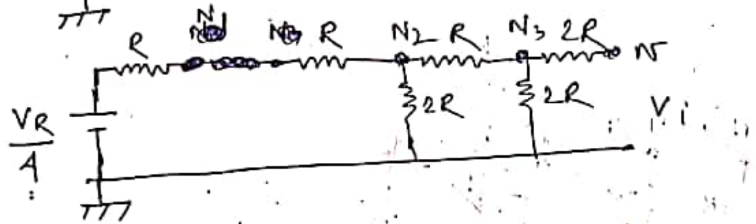
for next node $V_R/8$, in series with 3R, $A_1 \to V_R$

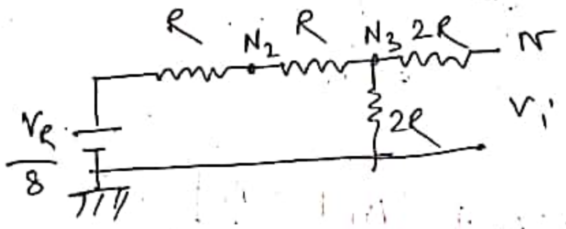
then $V_R/4$ " 3R $A_2 \to V_R$,

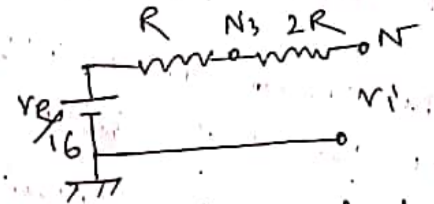
" $V_R/2$ " 3R $A_3 \to V_R$





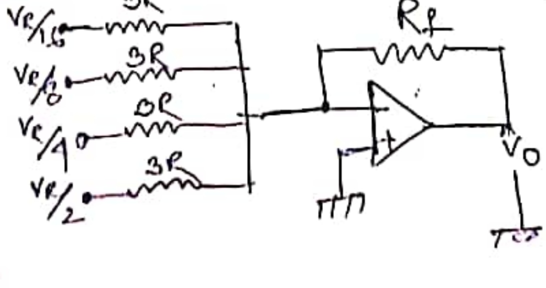






The value of equivalent resistance 3R in each case,

By superposition we can get the final equivalent circuit as,



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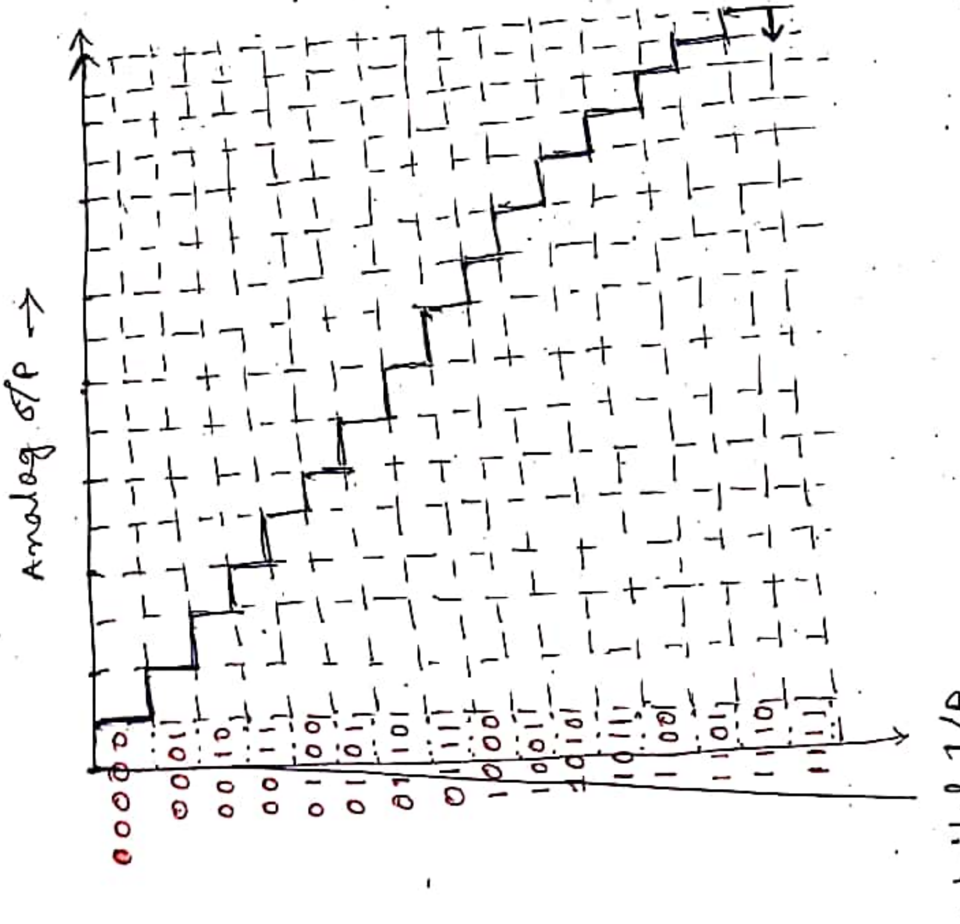
So, $V_0 = -\frac{R_f}{3R}\left(A_3 \cdot \frac{V_R}{2} + A_2 \cdot \frac{V_R}{4} + A_1 \cdot \frac{V_R}{8} + A_0 \cdot \frac{V_R}{16}\right)$

$$V_0 = -\frac{R_f}{3R} \cdot \frac{V_R}{2^4}\left(2^3 A_3 + 2^2 A_2 + 2^1 A_1 + 2^0 A_0\right)$$

- **Resolution:** In 4 bit converter the smallest change in the o/p voltage i.e. resolution is given by,

$$\frac{\text{Full scale voltage}}{\text{Number of steps}} = \frac{R_f}{3R} \cdot \frac{V_R}{2^4} = V_R \cdot \frac{R_f}{48R}$$

with $V_R = 5V$, $R_f = 3R$, the voltage resolution is the order of 0.3V. In 4 bit D/A, Binary digits varied from 0000 to 1111 (0→15) and the output of the converter will assume a staircase wave form with $2^4 - 1$ or 15 discrete steps.



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- REST PART OF UNIT - I
- Problems will be uploaded shortly

Reference : B. Ghosh (Electronics)

Mehta - Mehta

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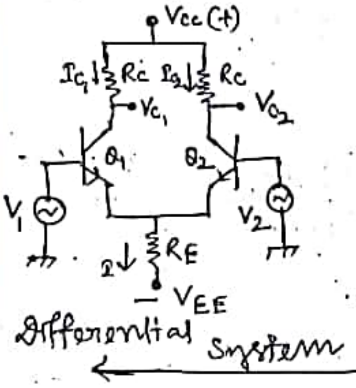
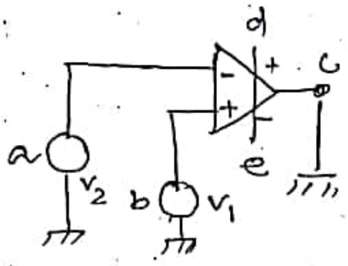
• CMRR :



An OPAMP is basically a differential amplifier with signal voltages v_1 and v_2, each measured w.r.to. ground.
$v_1 \rightarrow$ to non inverting terminal b
$v_2 \rightarrow$ — inverting " a

→ The o/p voltage 'v_o' measured at 'c' w.r.to gnd.



• In practice difference mode signal $v_d = v_1 - v_2$ and also average signal called common mode signal $v_c = \frac{v_1 + v_2}{2}$ are applied to produce the o/p voltages. So,

So, $v_o = A_1 v_1 + A_2 v_2$

A_1 = voltage gain when 'a' is grounded
A_2 = " " " 'b' "

So, $v_1 = v_c + \frac{1}{2} v_d$

$v_2 = v_c - \frac{1}{2} v_d$

$$v_o = \frac{1}{2}(A_1 - A_2) v_d + (A_1 + A_2) v_c$$

$$= A_d v_d + A_c v_c$$

So, $A_d = \frac{1}{2}(A_1 - A_2)$

$A_c = A_1 + A_2$

A_d = Voltage gain for difference signal.

A_c = Voltage gain for common signal.

So, C.M.R.R i.e. Common mode Rejection Ratio.

$$CMRR = \left|\frac{A_d}{A_c}\right| = \frac{\frac{1}{2}(A_1 - A_2)}{A_1 + A_2} = \frac{A_1 - A_2}{2(A_1 + A_2)}$$

• $CMRR = 20\log_{10}\left|\frac{A_d}{A_c}\right|$ in dB

A_d needs to be large and A_c needs to be small. The amplifier design should be such that the C.M.R.R is much larger than unity.

* CMRR is to be infinitely large.

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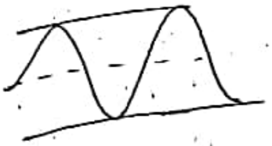
Slew Rate : (SR)



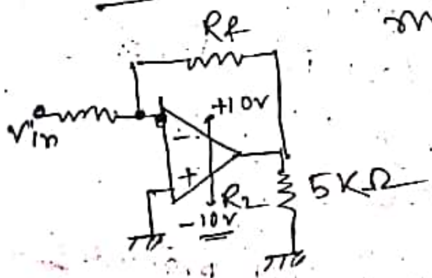
Slew rate of an OPAMP is a measure of how fast the output voltage can change and is measured in volts/μS..

— If S.R. of the OPAMP is 0.5 V/μS, it means that the o/p from the amplifier can change by 0.5V every μS. Since frequency is a function of time, the slew rate can be used to determine the maximum operating frequency of the OPAMP.

- Maximum operating frequency, $f_{max} = \frac{\text{Slew Rate}}{2\pi V_{pk}}$

V_{pk} → peak to peak o/p voltage.

- - **Determine Maximum operating frequency of the circuit, when, S.R = 0.5 V/μS : (Experimentally maximum peak to peak voltage ≅ 8V)**



So, $f_{max} = \frac{S.R.}{2\pi V_{p\text{-}p}} = \frac{0.5 V/\mu S}{2\pi \times 8}$ *

as, $0.5 V/\mu S = 500 KHz$

≃ 9.95 KHz → which is not seen to be very high o/p frequency. then the amplifier must would be operating at its maximum o/p voltage.

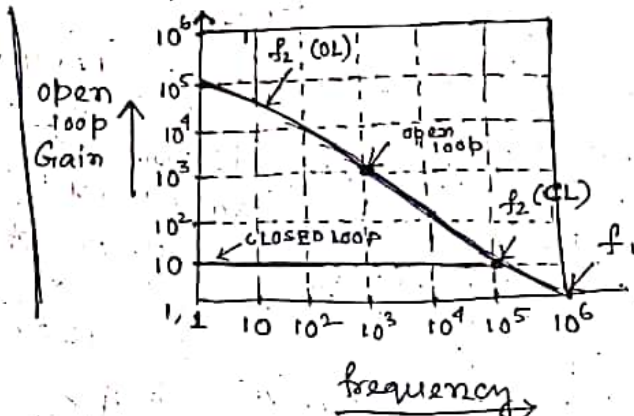
- - * 8V as, $+V_{sat} = +V_{supply} - 2 = 10 - 2 \simeq$ 8V

* - Now, if V_{pp} is small ≃ 100mV = 0.1V.

$$f_{max} = \frac{0.5 V/\mu s}{2\pi \times 0.1} = \frac{500 KHz}{2\pi \times 0.1} = 796 KHz$$

So, the OPAMP is to be operated at much higher frequency thus when being used small signal amplifier than when being used as a large signal amplifier.

Frequency Response of an OPAMP :



* frequency response of typical OPAMP IC μA 741

As a feedback amplier of several stages an OPAMP can show gain instability, for this some commercial OPAMP are internally composed for stability. The internal compensating capacitor makes the open loop Band width or upper cut off frequency $[f_2(OL)]$ i.e. the fre. at which the gain drops to $1/\sqrt{2}$ of the d.c. gain, very low. Lower cut off fre. is '0' here. for IC 741: the cutoff f_2 (OL) is order of 10 Hz. So, open loop OPAMP is not suitable for Linear applications (Q)

For ideal OPAMP. B.W. is practically infinite. but practically OPAMP under open loop configuration B.W. is low. So the OPAMP considered under of 10 Hz order only. when the gain is somewhat closed loop configure. low.

... When negetive feedback is used overall B.W. increases, Smaller is the closed loop gain (A_{CL}) used, the higher is the upper cut frequency f_2(CL). However product $A_{CL} f_2$(CL) is constant and is equal to open-loop unity gain frequency (funity). This product is known as Gain Band Width product (GBW)

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∴ when it is calculated for unit gain, the quantity is called unit gain Band width (UGB).

⊛ General OPAMP. under that operation S.R = 0.5 V/μs

Characteristics of the frequency Response :

i) Maximum operating frequency of an OPAMP is given by $f_{max} = \frac{S.R.}{2\pi V_{P-P}}$

- peak output voltage limits the maximum operating frequency.

ii) When the maximum operating frequency of an OP-AMP is exceed, the result is a distorted output waveform.

iii) Increasing the operating frequency of an OP-AMP beyond certain point
   a) Decrease the maximum output voltage swing.
   b) Decrease the open loop voltage gain.
   c) Decrease the input impedence.
   d) increase the output impedence.

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