Resolution = $\dfrac{\text{Full scale Range FSR}}{2^{\text{no. of bits}}}$

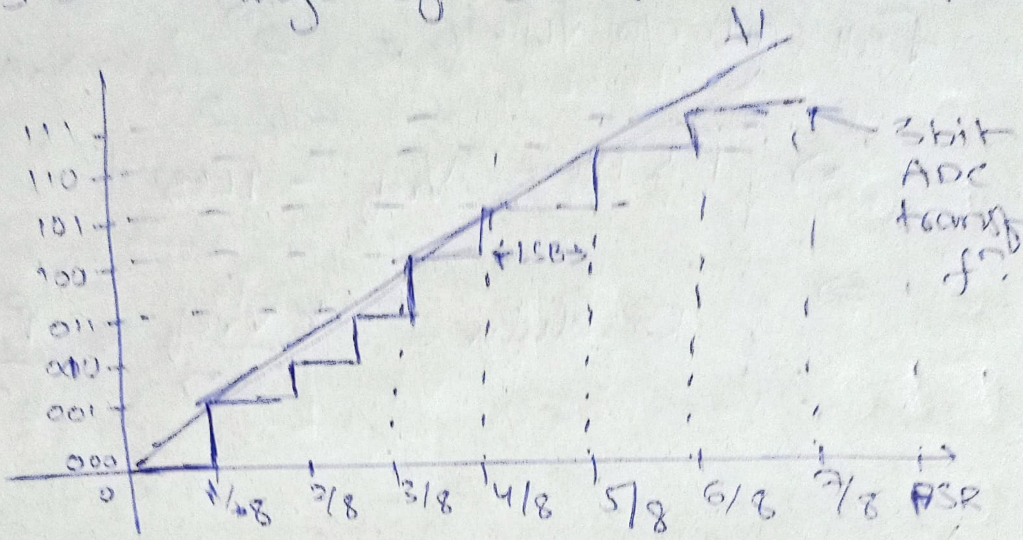
$= \dfrac{V_{max} - V_{min}}{2^n}$

$\boxed{\text{FSR} = \dfrac{V_{ref}}{2^n}} = \text{Resolution}$

If full scale voltage of 3 bit ADC is 2V then resolution $= \dfrac{2V}{2^3} = \dfrac{1}{4}$ //

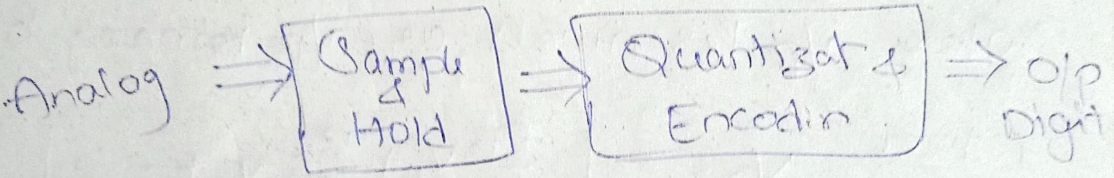
Transfer f^n of ADC & DAC

at 3 bit range of 0-1V



$\boxed{\text{Quantization Error} = 1\ LSB}$

BDG of ADC :-



Important parameters of ADC & DAC

→ Resolution

→ Reference voltage | full scale Range

→ Sampling time & Conversion time | settling time

→ Gain Error & Offset Error.

→ Non-Linearity (Integral & Differential)

→ Total Harmonics. THD

Binary weighted Resistor DAC

Full scale o/p voltage $= \frac{2^n - 1}{2^n} \times V_{ref}$

$\Rightarrow$ $\boxed{FSD = V_{ref} - 1LSB}$

$\Rightarrow$ $\boxed{\text{Resolution} = \frac{k V_{ref}}{2^n} = \frac{FSD}{2^n - 1}}$

$V_o = -\frac{R_f}{R} V_{ref} \left(\frac{V_1}{R_1} + V \right.$

$\Rightarrow$ A Binary weighted Resistor DAC is simply a Inverting summing amplifier where i/p terminals are i/p binary bits

where $V_o = -\left[\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2 + \cdots \right]$

In Binary weighted resistor, o/p is a form of $R_1 = R$, $R_2 = 2R$, $R_3 = 8R$ 2^n order form

$\Rightarrow$ $V_o = -R_f \left[\frac{V_1}{R} + \frac{V_2}{2R} + \frac{V_3}{8R} + \cdots \right]$

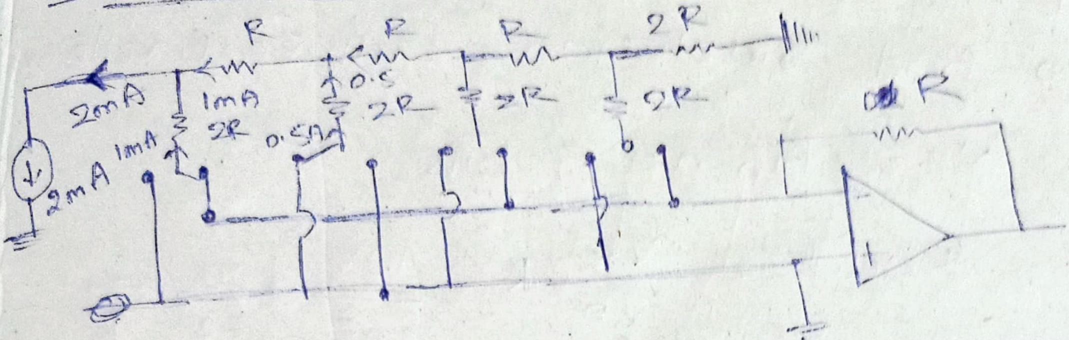
$V_o = -\frac{R_f}{R} \left[\frac{V_1}{1} + \frac{V_2}{2} + \frac{V_3}{8} + \frac{V_4}{16} + \cdots \right]$

where V_1 is MSB } Data bits
V_n is LSB

$\therefore V_o = -R_f \left[B_0 . V_{ref} + B_1 V_{ref} \ldots \right]$

$\Rightarrow V_0 = -\frac{R_f}{R} \cdot V_{ref} [$

Inverted R-2R LADDER DAC

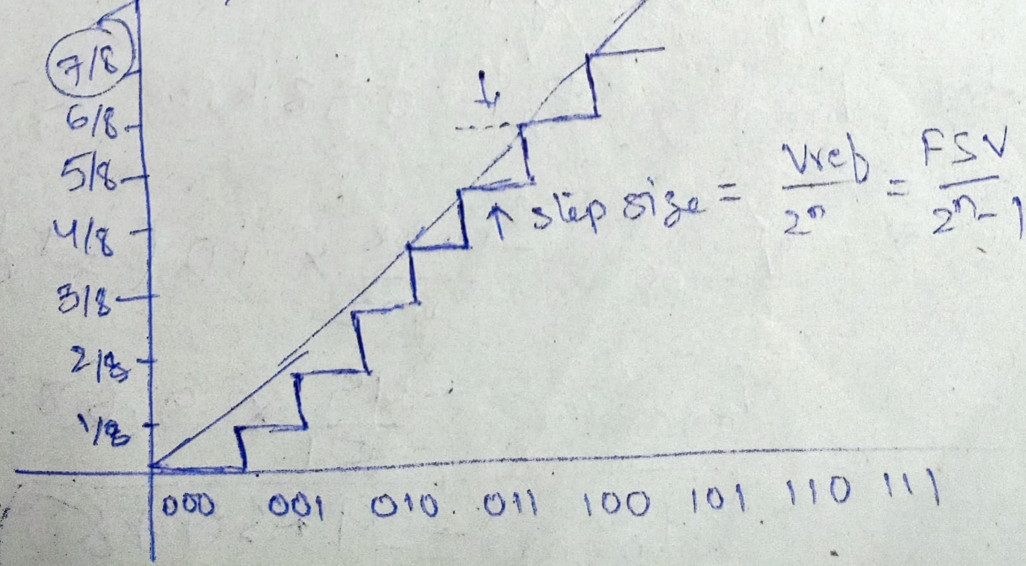


DAC 3 bit when k = 1 :

Digital			Analog
0	0	0	0
0	0	1	Vref/8
0	1	0	2Vref/8
0	1	1	3Vref/8
1	0	0	4Vref/8
1	0	1	5Vref/8
1	1	0	6Vref/8
1	1	1	7Vref/8

No. of steps $= \frac{V_{in}}{\text{resolu}}$

$\Rightarrow$ Transfer function :-



step size $= \frac{V_{ref}}{2^n} = \frac{FSV}{2^n - 1}$

① find V_{max} & V_{min} for 11111 i/p with binary weighted DAC. $V_{ref} = 10V$, $R_f = R = 1k\Omega$, Resistance tolerance 2%. Also find resolusion, full scale voltage

Ans: No. of bits n = 5 bits

$$\text{Resolution} = \frac{V_{ref}}{2^n} \times K = \frac{10V}{2^5} = \frac{10}{32} = \frac{5}{16}.$$

In Ideal case,

$$V_o = -\frac{R_f}{R} V_{ref}\left[\frac{d_1}{2} + \frac{d_2}{4} + \frac{d_3}{8} + \frac{d_4}{16} + \frac{d_5}{32}\right]$$

$$V_o = -\cancel{10}^{5}\left[\frac{16+8+4+2+1}{\cancel{32}\,16}\right]$$

$$V_o = -5 \times \frac{31}{16} = \frac{-75}{8} = -9.6875$$

for V_{max}; $R_f = 1.02\,k\Omega$; $R = 0.98\,k\Omega$

$$\Rightarrow V_{o\,max} = \frac{-1.02}{0.98} \times 10\left(\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \frac{1}{32}\right)$$

$$V_{o\,max} = -\frac{51}{49} \times 9.6875 = -10.0829.$$

for V_{min}; $R_f = 0.98\,k\Omega$, $R = 1.02\,k\Omega$

$$\Rightarrow V_{min} = \frac{-0.98}{1.02} \times 10\left(\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \frac{1}{32}\right)$$

$$V_{min} = \frac{-49}{51} \times 9.6875$$

$$\boxed{V_{min} = -9.3078}$$

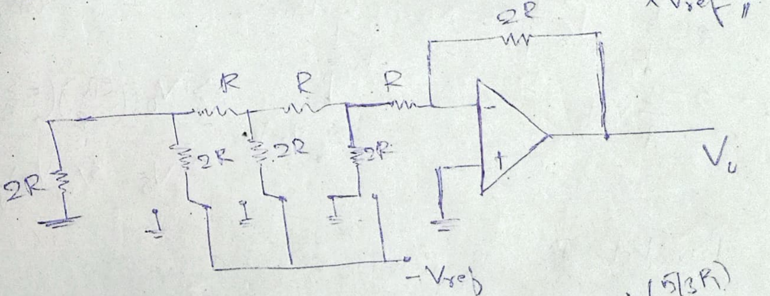
$$\text{full scale voltage} = \frac{2^n - 1}{2^n} \times V_{ref}$$

$$= \frac{31}{32\,16} \times \cancel{10}\,5 = \frac{155}{16}$$

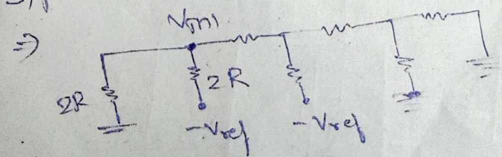
$$\boxed{fsv = 9.6875}$$

→ for accurate analog o/p tolerance should be less.

R-2R Ladder:- $V_o = \left[\frac{a_n}{2^n} + \frac{a_{n-1}}{2^{n-1}} + \dots + \frac{a_2}{2^2} + \frac{a_1}{2^1}\right] \times V_{ref}$



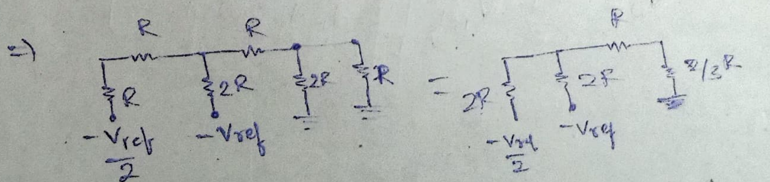
I/p = 011

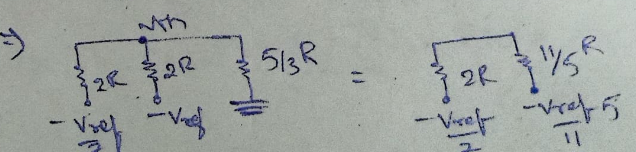


$$\frac{-V_{ref}(5/3R)}{2R + 5/3R}$$

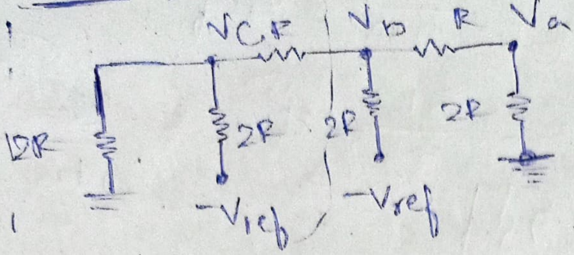
$$-V_{ref}\frac{5}{11}$$

$$V_{Th_1} = (-V_{ref})\frac{2R}{4R} = \frac{-V_{ref}}{2}\ ;\ R_{Th} = R\ (\because 2R \| 2R)$$





for 011



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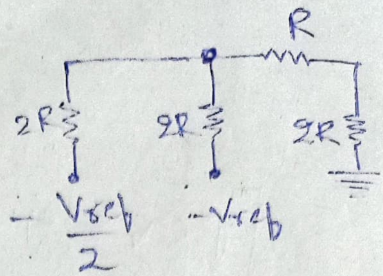
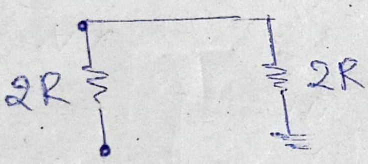


$V_c = \frac{-V_{ref}}{2} \Rightarrow \frac{\frac{-V_{ref}}{2} - k}{\cancel{2R}} = \frac{k + V_{ref}}{\cancel{2R}}$

$R_{Th} = R$

$\Rightarrow \frac{-3V_{ref}}{2} = 2k \Rightarrow \boxed{k = -\frac{3}{4}V_{ref}}$

$\frac{-\frac{3}{4}V_{ref} \times \frac{1}{2}}{4R}$



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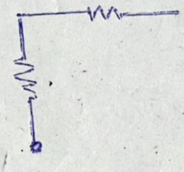
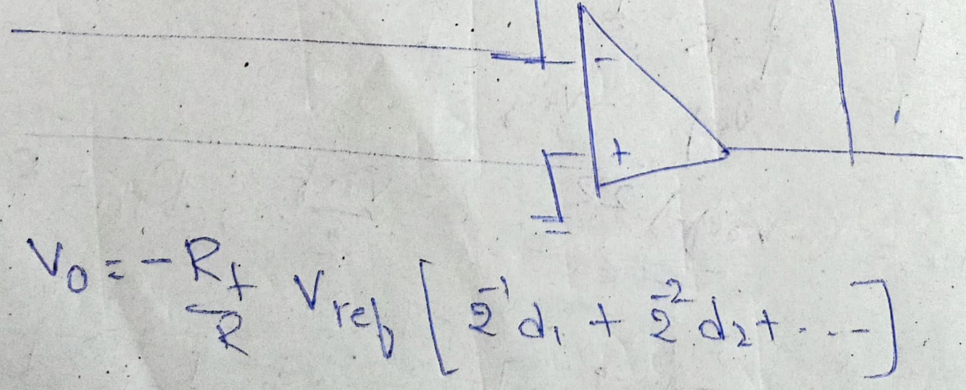


$\Rightarrow V_0 = \left(\frac{2R}{2R}\right)\left(-\frac{3}{8}V_{ref}\right)$

$\Rightarrow \boxed{V_0 = 3/8\, V_{ref}}$

Inverted R-2R LADDER



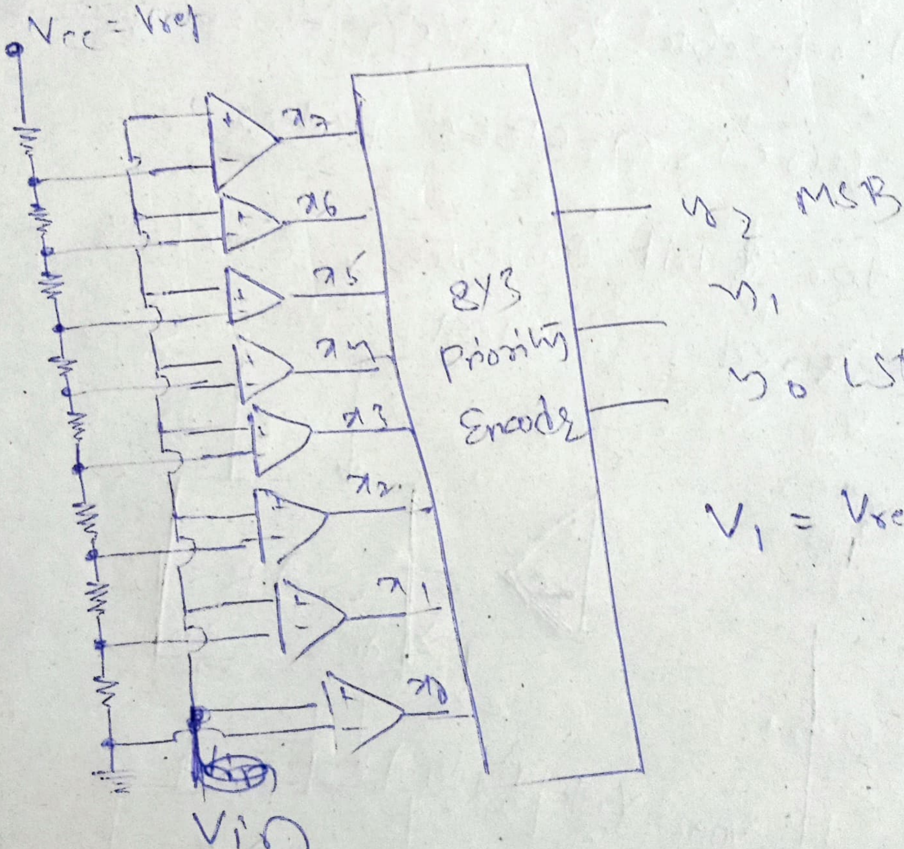
$V_0 = -\frac{R_f}{R} V_{ref}\left[2^{-1}d_1 + 2^{-2}d_2 + \dots\right]$

ADC:- Types:- (i) Direct type
(ii) Integrating type.

(i) Direct type ADC has: Flash ADC, counter type ADC, tracking / Servo converter, Successive approximation type.

(ii) Integrating type:- Charge balancing ADC, Dual slope ADC.

Flash / parallel comparator ADC



$V_1 = V_{ref}\left(\frac{R}{8R}\right)$

It is made of voltage Divider made of precision rectifier & comparators (High speed). also a priority Encoder

→ It need only one clock cycle

→ let $V_{in} = 5.3V$, $V_{ref} = 8V$

⇒ i/p terminals have

0 0 1 1 1 1 1 1
x_7 x_6 x_5 x_4 x_3 x_2 x_1 x_0

Priority is 5
so o/p is 101

Successive Approximation Type ADC

→ Conversion time period doesn't depend upon on i/p voltage

$T_C \propto$ no. of bits

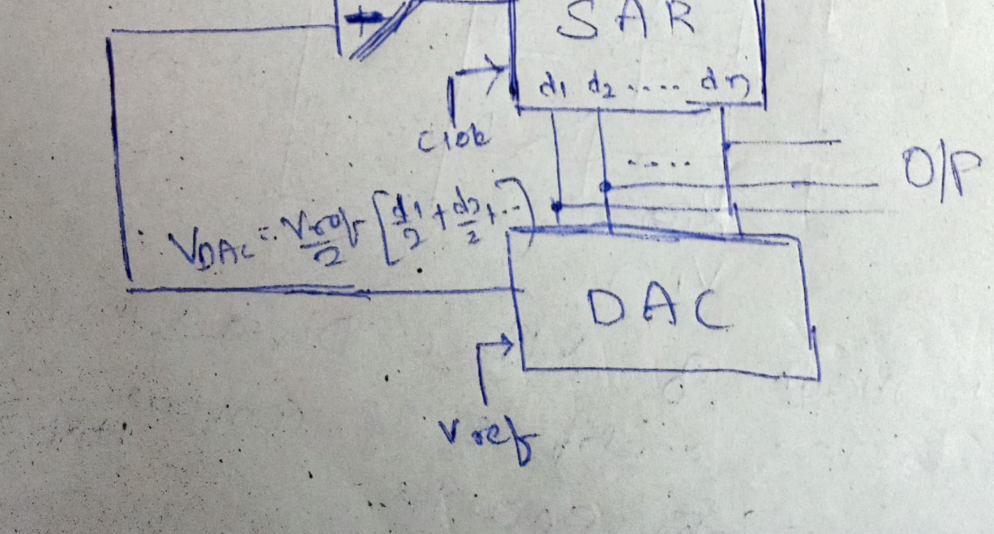
$\frac{1}{2} + \frac{1}{8} = \frac{5}{8}$

$\frac{1}{2} + \frac{1}{8} + \frac{1}{16}$

→ A reference is taken for comparison with o/p

Requires n-clock pulses

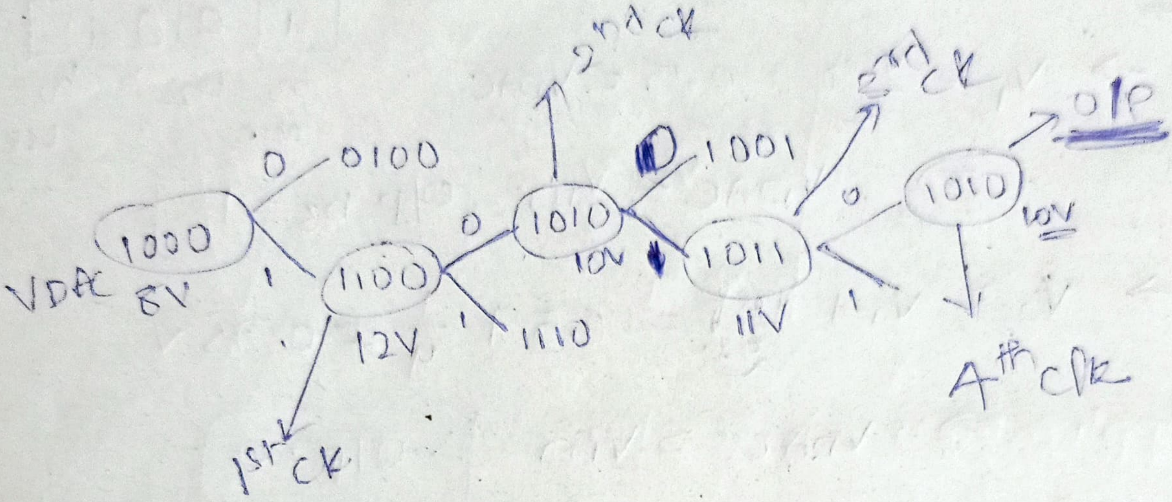
⇒ for 8 bit converter, 8-clock pulses are required.



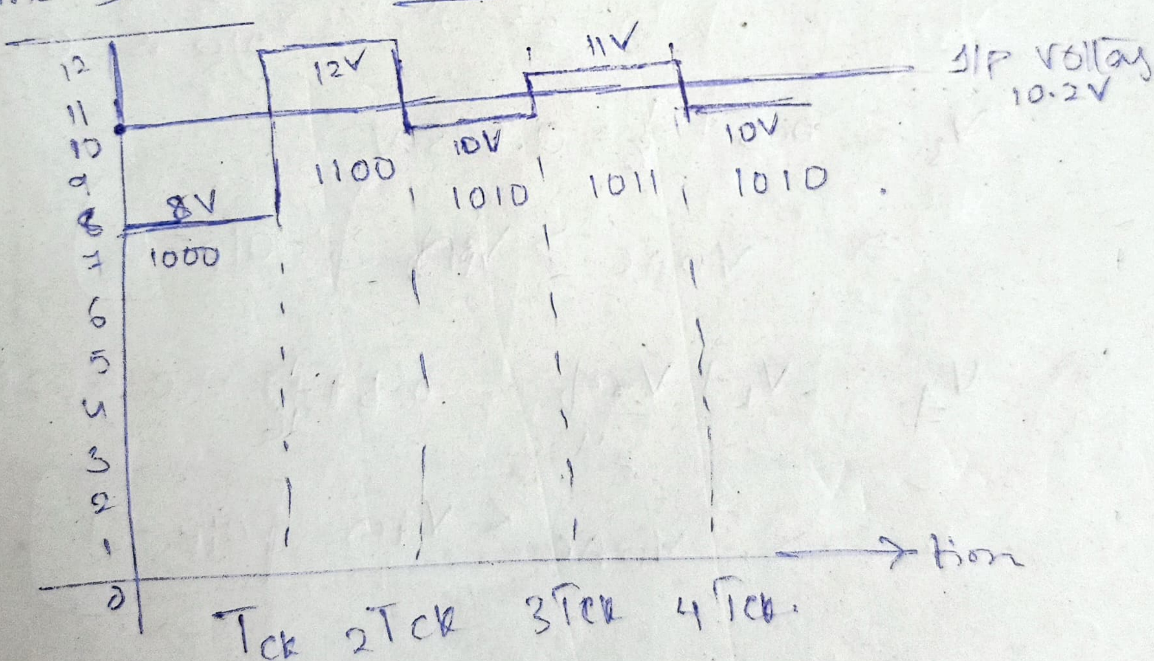
Q:- Analug i/p $V_{in} = 10.2v$ & $V_{ref} = 16v$.

Initially MSB = 1000 ⇒ $V_{DAC} = 8V$

assuming 4-bit o/p no. of clock pulses is 4



Time Duration Graph / conversion time of SAR



⇒ Conversion time is constant & indepent

$T_C = N\,T_{clk}$; N = no. of bits

Q:- To find digital Equivalent of $V_{in} = 0.6V$ for 4 bit ADC & $V_{ref} = 1V$

Ans:- → for b_3 i.e, MSB

1	0	0	1
b_3	b_2	b_1	b_0
MSB			LSB

→ $V_1 = \frac{V_{ref}}{2} = 0.5 = V_{DAC}$

⇒ $V_{DAC} < V_{in}$ $\boxed{O/P\ b_3 = 1}$

→ $V_2 = V_1 + \frac{V_{ref}}{2^2} = 0.5 + \frac{1}{4} = 0.75V$

⇒ $V_{DAC} > V_{in}$ $\boxed{\therefore O/P = 0}$

→ $V_3 = V_1 + V_2 + \frac{V_{ref}}{2^3}$ [here $V_2 = 0$ ∵ its O/P is 0.]

⇒ $V_3 = 0.5 + \frac{1}{8} = 0.625V$

⇒ $V_{DAC} > V_{ref}$ $\boxed{\therefore O/P = 0}$

⇒ $V_4 = V_1 + \frac{V_{ref}}{2^4} = 0.5 + \frac{1}{16} = 0.5625$

⇒ $V_{DAC} < V_{in}$ $\boxed{O/P = 1}$

1001

⇒ $(1 \times 2^3 + 0 + 0 + 2^0 \times 1) = 9$

$(V_{out})_{0.6}$ for digital $= \frac{V_{ref} \times i/p\ volt}{2^n}$

$= \frac{1 \times 9}{2^4} = 0.5625$

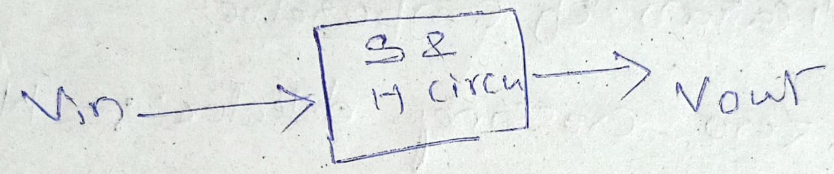
Unit - ~~III~~ : ~~Sam~~

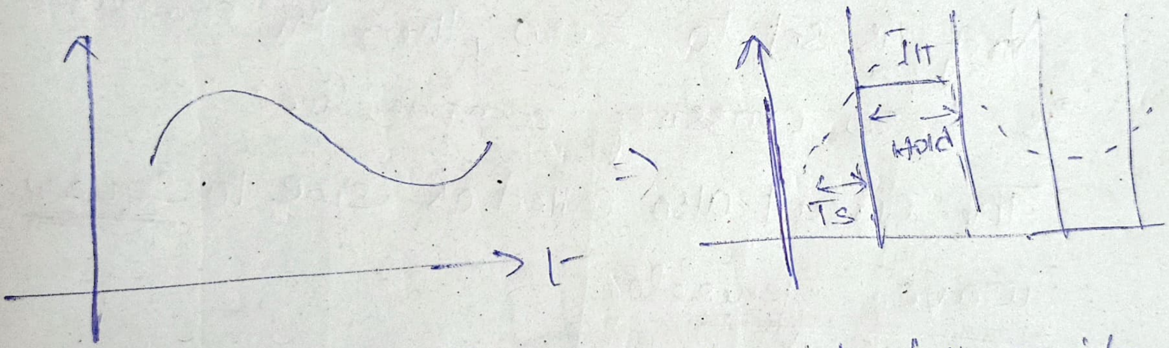
→ Sample & Hold circuit

~~(i)~~ Used in sampling process, to make i/p signal discrete.

⇒ Used to convert Analog to Digital.

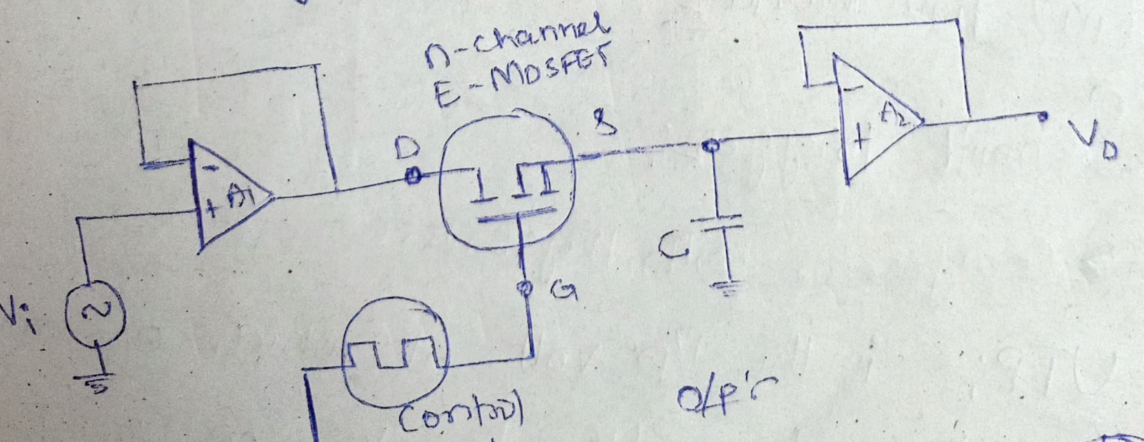
⇒ Samples i/p signal & holds it for some time period



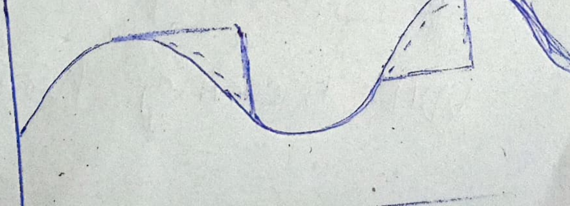


⇒ During T_S period o/p follows i/p

⇒ During T_H time O/p is constant hold

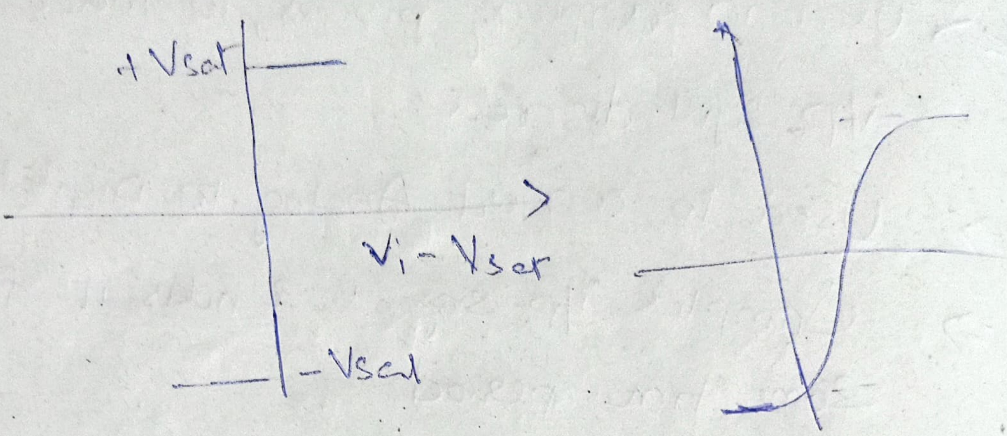


o/p :



Comparators:-

Transfer fn Ideal & practical



Applications of comparator

(i) Zero crossing detector :- When Vref is set to zero, then the comparator is zero crossing comparator.

The circuit also called as sine to square wave generator

(ii) Window Detector :- (LED turn on/off)

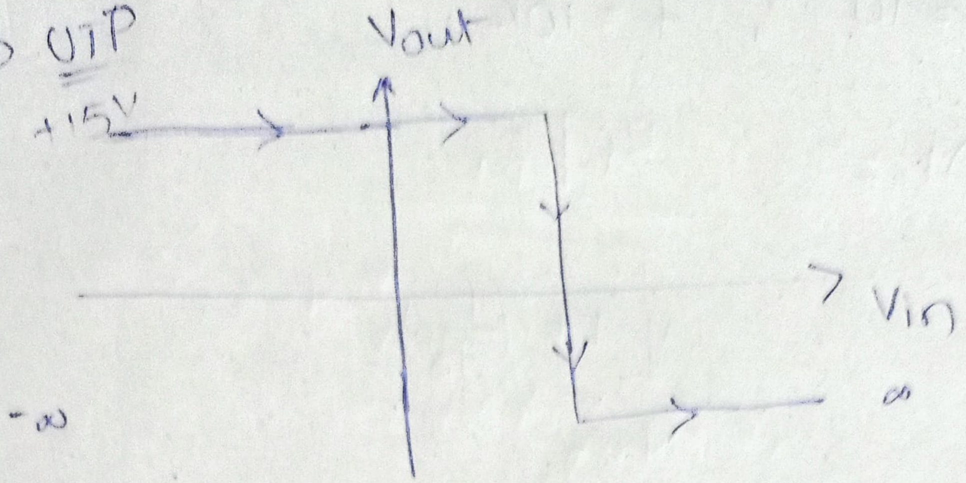
(iii) Time Marker :-

Schmitt Trigger:-

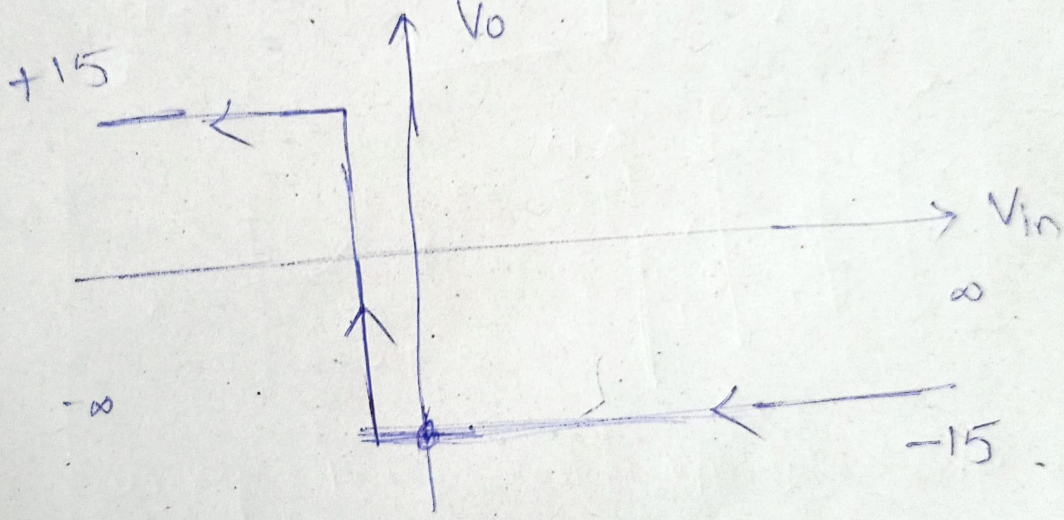
→ Comparator with Hysteresis

UTP:- is the i/p volt at which o/p makes transition from +Vcc to -Vcc as the i/p volt making forward dirn

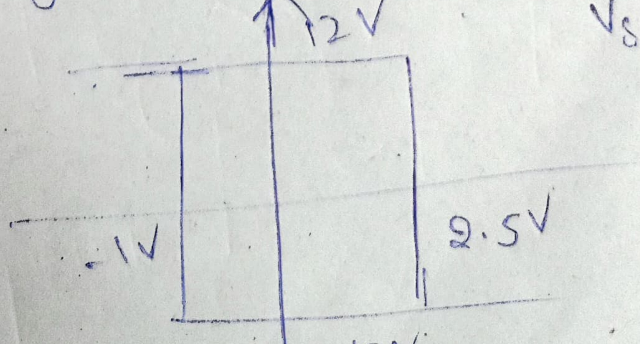
⇒ UTP



LTP :- is the i/p volt at which o/p volt makes transition from $-V_{cc}$ to $+V_{cc}$ when i/p volt is moving reverse direction



Design a Schmitt trigger by using the Hysteresis given below



$V_{sat} = \pm 12$

$V_{UTh} = 2.5$

$V_L = -1V$

$A = 10$; $f = 10K$

$$|A| = \frac{R_f / R_1}{\sqrt{1 + \left(\frac{f}{f_a}\right)^2}}$$

peak gain or 3dB gain

$|A| = R_f / R_1 = 10$ let $R_1 = 10k$

$\boxed{R_f = 100k}$

let max freq of integr $f_b = 10kHz$

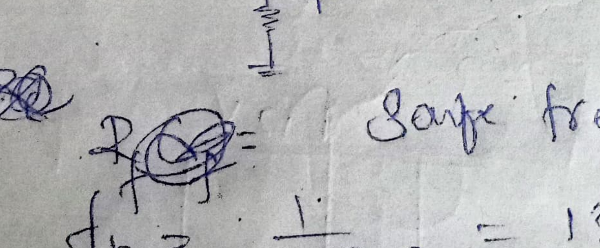
Corner freq is f_a

$\Rightarrow f_b = 10 f_a$

$\Rightarrow \boxed{f_a = 1KHZ}$

Corner freq $f_a = \frac{1}{2\pi C_f R_f}$

(2) (i)



$R_f = 1.2M\Omega$
$R_1 = 120k\Omega$
$C_f = 10nF$

(ii) Safe freq $f_a = 10 f_b$

$f_b = \frac{1}{2\pi R_f C_f} = 13.26$ kHz

$\boxed{f_a = 132.6kn}$

(iii) $V_o = A \cdot V_{in}$

given $V_{in} = 5V$, & $f = 10KH$

$$\Rightarrow \quad A = \frac{R_f/R}{\sqrt{1+(f/f_a)^2}}$$

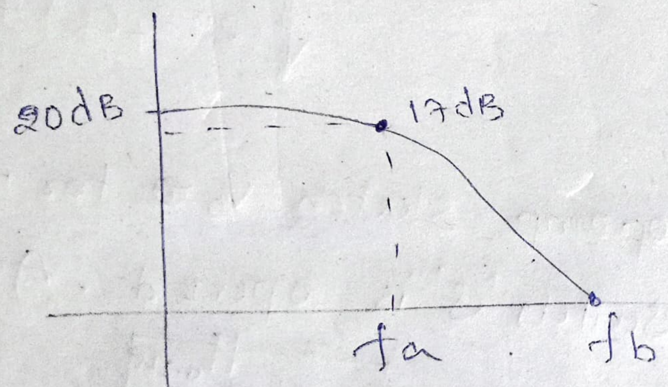
$$A = \frac{100/10}{\sqrt{1+\left(\frac{10}{136.86}\right)}} = 0.01326$$

$$\Rightarrow \boxed{V_o = 0.01326 \times 5 = 66.3\,mV}$$

(3) Sketch freq^n response.

Given $R_1 = 120k\Omega$, $R_f = 1.2M\Omega$, $C_f = 10n$

$|A| = 20\log_{10}^{10} = 20.$



(4) find R_1 & R_f in lossy integrator so that peak gain is 20dB & the gain is 3dB from its peak $\omega = 10{,}000$. $C_f = 0.01\mu f$

Ans'r/ Given $20\log|A| = 20\log R_f/R_1$

max gain / dc gain = 20

$$\Rightarrow 20 = 20\log R_f/R_1$$

$$\Rightarrow \frac{R_f}{R_1} = 10$$

$$f = \frac{\omega}{2\pi} = \frac{10,000}{2\pi}$$

3dB gain is 20 - 3 = 17 dB

$$\Rightarrow \quad 17\,dB = \frac{R_f/R_1}{\sqrt{1+(f/f_a)^2}} \qquad \frac{9\sqrt{21}}{17}$$

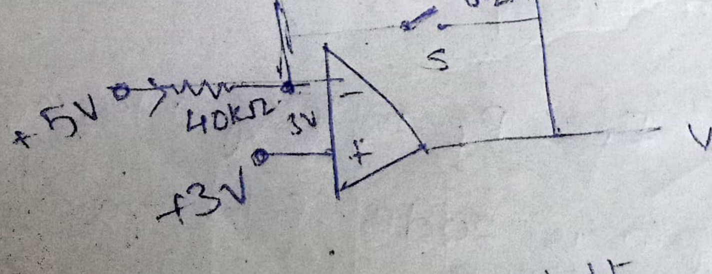
$$\Rightarrow \quad \frac{17^2}{10^2} = \frac{1}{1+(f/f_a)^2}$$

$$\Rightarrow \quad 1+(f/f_a)^2 = (10/17)^2 = \frac{-189}{289}$$

$\Rightarrow$

$$\Rightarrow \quad |A| = \frac{R_f/R_1}{\sqrt{(2\pi R_f C_f)^2+1}}$$

(4) for op amp sketch V_o for 50msec after switch 'S' is opened. Assume ideal.



Ansr

$$\frac{5-3V}{40\times10^3} = \frac{-1}{C_f R_f}\int v_i\,dt$$

$$\frac{1}{10^4} = \frac{-1}{\quad}$$

$$\frac{V_i - 3}{R_1} = C_f \frac{d}{dt}(V_y - V_o)$$

$$\Rightarrow \frac{2}{40K\Omega} = 0.2\times10^{-6} \frac{d}{dt}(3 - V_o)$$

$$\Rightarrow V_o = \int \frac{2}{8\times10^{-3}} dt$$

$$V_o = \frac{2}{8\times10^{-3}} \int_0^{50ms} dt$$

$$V_o = \frac{\cancel{2}}{\underset{4}{\cancel{8}}\times\cancel{10^{-3}}} \overset{25}{\cancel{50}}\times\cancel{10^{-3}}$$

$$\boxed{V_o = -12.5V}$$

Total o/p voltage

$$V_o = \int_0^{50} v_i + V_{out}\Big|_{t=0}$$

$$= -12.5 + 3 = -9.5V$$

$$\Rightarrow V_{out} = \frac{-1}{C_f R_1} \int_0^{t_1} (V_i - V_y)\, dt$$

$$\Rightarrow \int_0^{t_1} dt = \frac{-9.5\times8\times10^{-3}}{2}$$

$$\Rightarrow t_1 = 38\times10^{-3} = 38ms$$