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For N=3

$$O/p = V_{ref}\left[\frac{b_0}{8} + \frac{b_1}{4} + \frac{b_2}{2}\right]$$

For n-bit:

$$V_{R-2R} = V_{ref}\left[\frac{b_0}{2^n} + \frac{b_1}{2^{n-1}} + \frac{b_2}{2^{n-2}} + \cdots \frac{b_{n-1}}{2^1}\right]$$

Hence,
O/p voltage is:

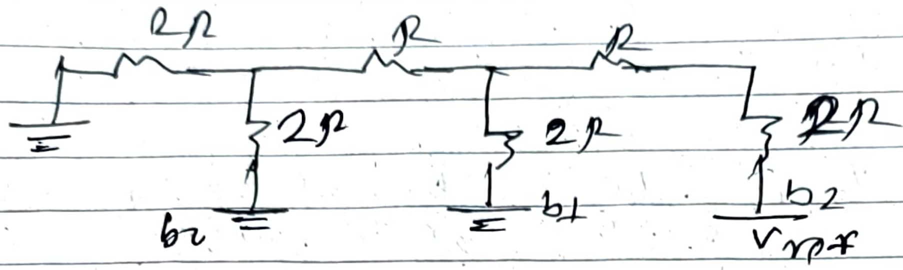
$$V_0 = V_{ref}\left(\frac{-R_f}{R}\right)\left[\frac{b_0}{2^n} + \frac{b_1}{2^{n-1}} + \frac{b_2}{2^{n-2}} + \cdots \frac{b_{n-1}}{2^1}\right]$$

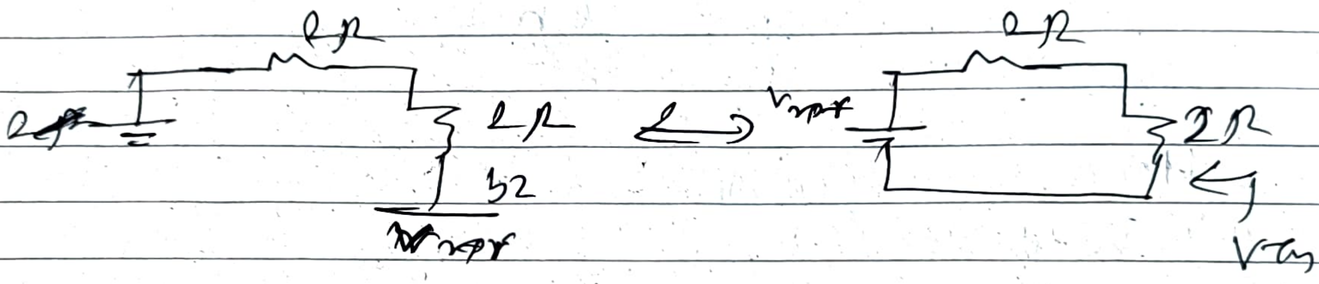
Also,

$$V_0 = -V_{ref}\left(\frac{R_f}{R}\right)\sum_{i=0}^{i=n-1}\frac{b_i}{2^{n-i}}$$

Again,

b_2	b_1	b_0
1	0	0





$$V_{Th} = \frac{2R}{2R+2R} \times V_{ref} = \frac{V_{ref}}{2}$$

Let $V_{ref} = 0$

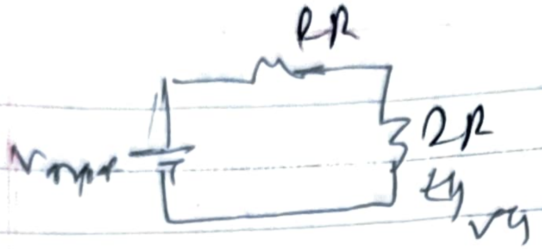
$R_{Th} = 2R \parallel 2R = R$

Hence the o/p of ladder network $= \frac{V_{ref}}{2}$

Hence

b_2	b_1	b_0	
0	0	1	$\rightarrow V_{ref}/8$
0	1	0	$\rightarrow V_{ref}/4$
1	0	0	$\rightarrow V_{ref}/2$

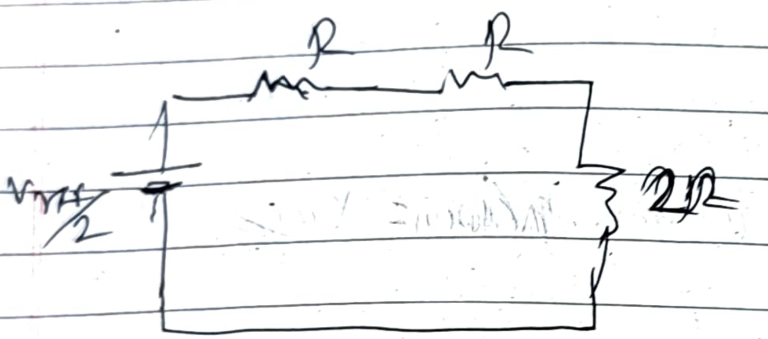
1 1 1 $\rightarrow \frac{V_{ref}}{2} + \frac{V_{ref}}{4} + \frac{V_{ref}}{8}$

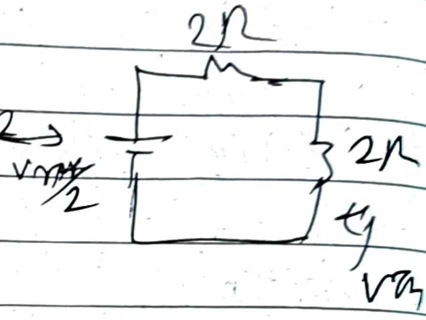


$$V_{Th} = \frac{2R}{2R+2R} \times V_{ref} = \frac{V_{ref}}{2}$$

Let, $V_{ref} = 0$,

$R_{Th} = 2R \parallel 2R = R$





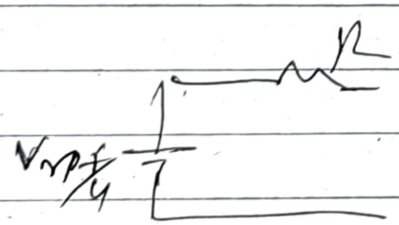
$$\therefore \quad V_{Th} = \frac{2R}{2R+2R} \times \frac{V_{ref}}{2}$$

$$= \frac{V_{ref}}{4}$$

Let, $V_{ref}/2 = 0$

$R_{Th} = 2R \parallel 2R = R$

$\therefore$



Hence, o/p of ladder ~~n/w~~ network $= \frac{V_{ref}}{4}$

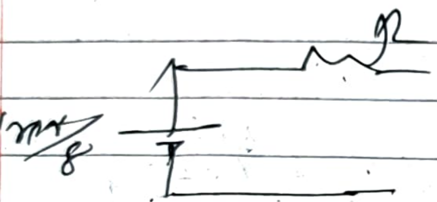
0 0 1 → $\frac{V_{ref}}{8}$
0 1 0 → $\frac{V_{ref}}{4}$
1 0 0 → $\frac{V_{ref}}{2}$

$V_{Th} = \frac{2R}{2R+2R} \times \frac{V_{ref}}{4}$

$\therefore V_{Th} = \frac{V_{ref}}{8}$

Let $\frac{V_{ref}}{4} = 0$.

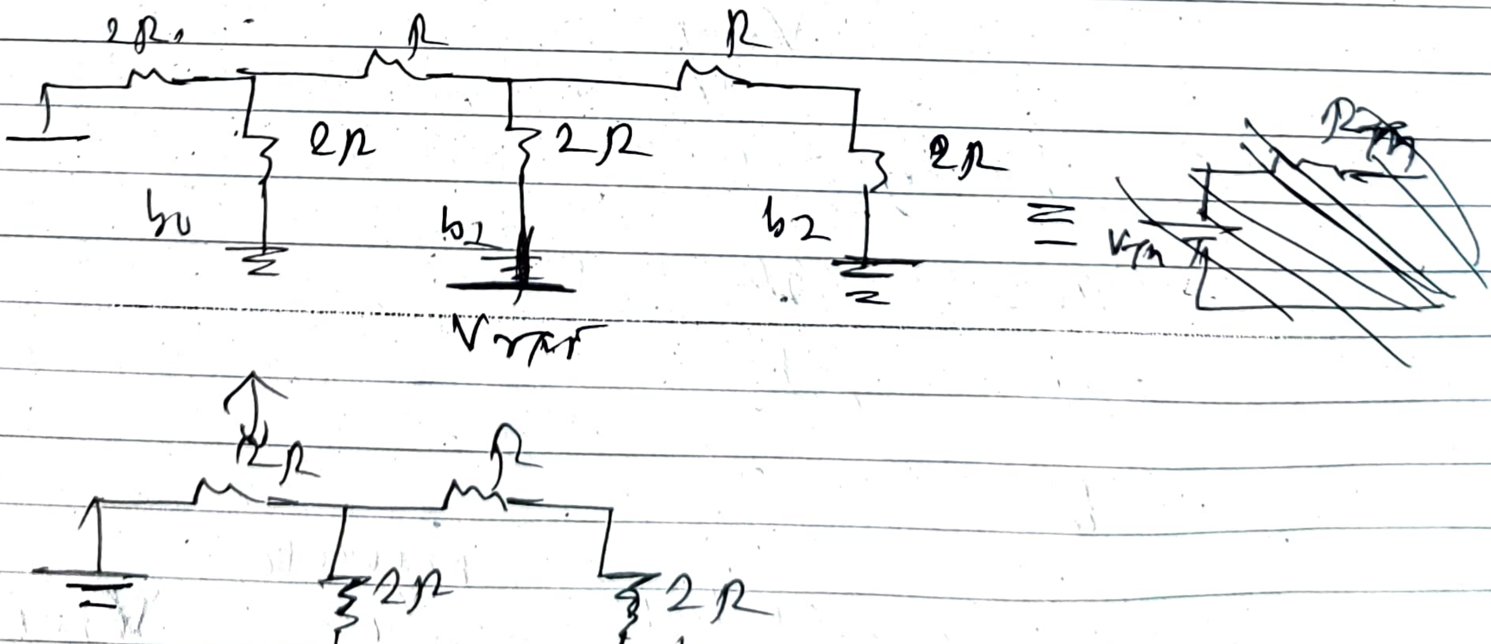
$R_{Th} = 2R \parallel 2R = R$

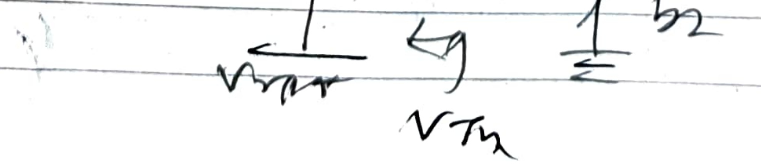


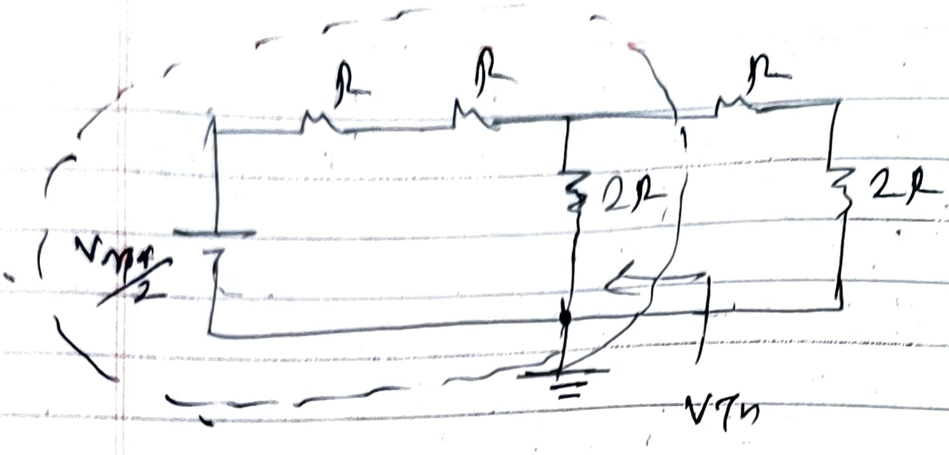
Hence, o/p of ladder ~~network~~ = $\frac{V_{ref}}{8}$

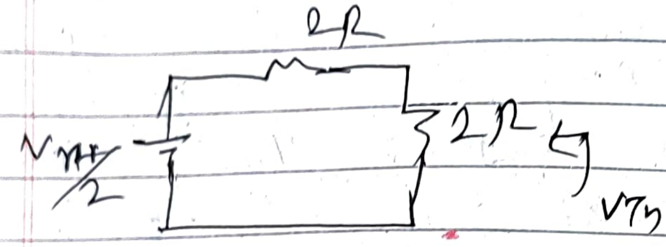
Again:

b_2	b_1	b_0
0	1	0







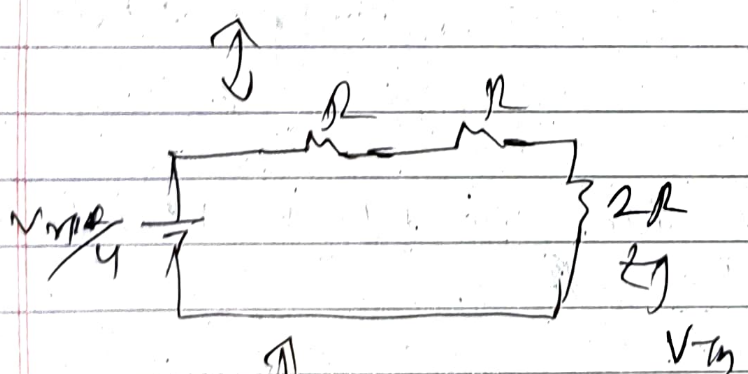


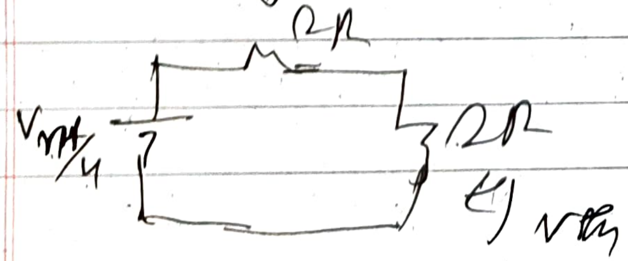
$$V_{Th} = \frac{2R}{2R+R+R} \times \frac{V_{ref}}{2}$$

So $V_{Th} = \frac{V_{ref}}{4}$

Lets $V_{ref}/2 = 0$

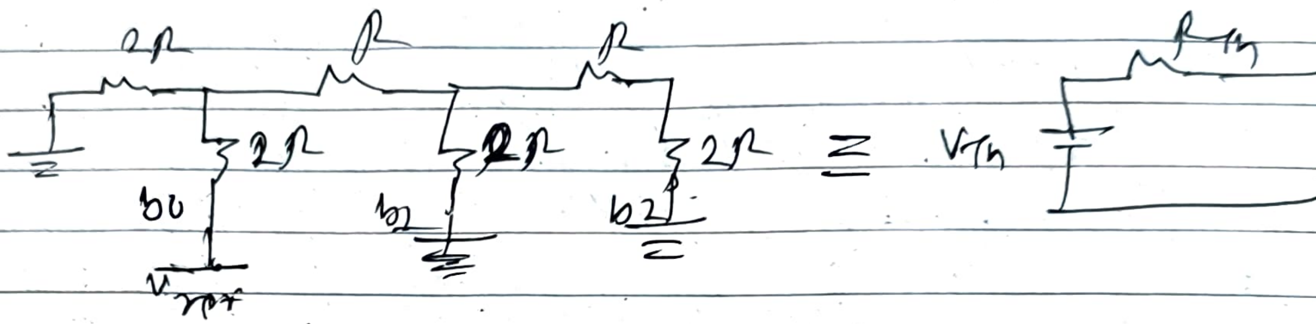
$R_{th} = 2R // 2R = R$





We assume at a time only one switch is on and by using superposition theorem, we find the overall o/p voltage.

b_2	b_1	b_0
0	0	1



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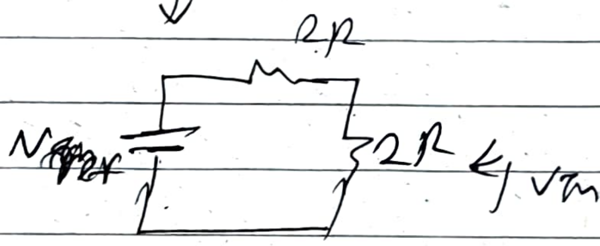

$$V_{Th} = \frac{2R}{2R+2R} \times V_{ref}$$

$$V_{Th} = \frac{V_{ref}}{2}$$

Let $V_{ref} = 0$, (to find equivalent resistance)

$$R_{Th} = 2R \,||\, 2R = R$$

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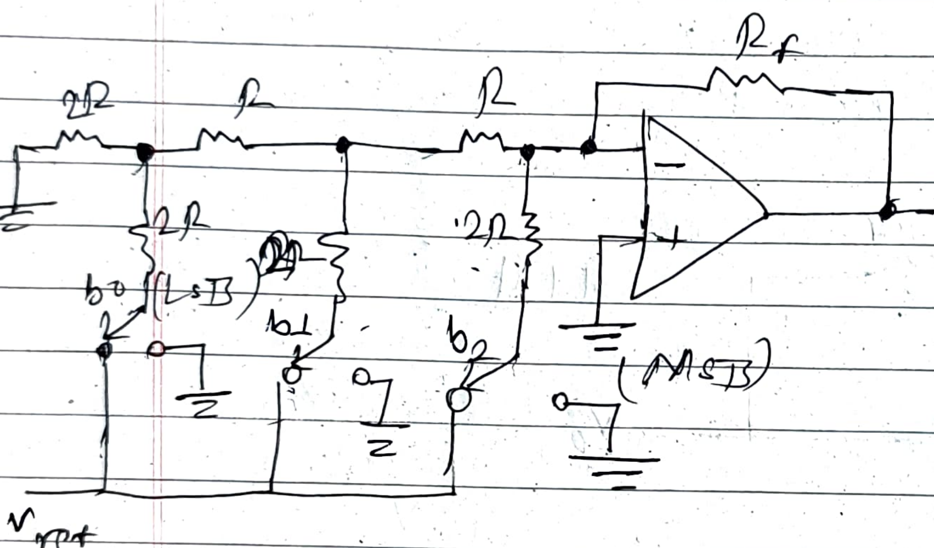
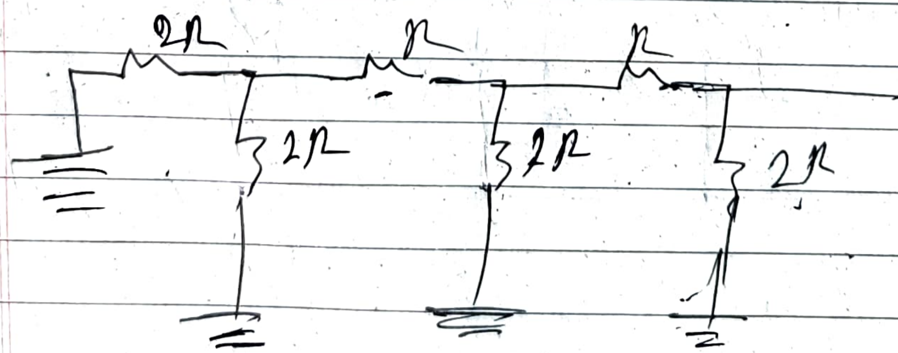
2) R – 2R ladder DAC. (3 bits)

→ uses only two values of resistors
→ Easy and accurate fabrication is possible.
→ Easily scalable to any desired number of bits.
→ o/p resistance is R, regardless of no. of bits.



R – 2R
Equivalent Network resistance is always R

Illustration.
R – 2R → Equivalent Resistance → R



$R_{eq} = R_{th} = R$