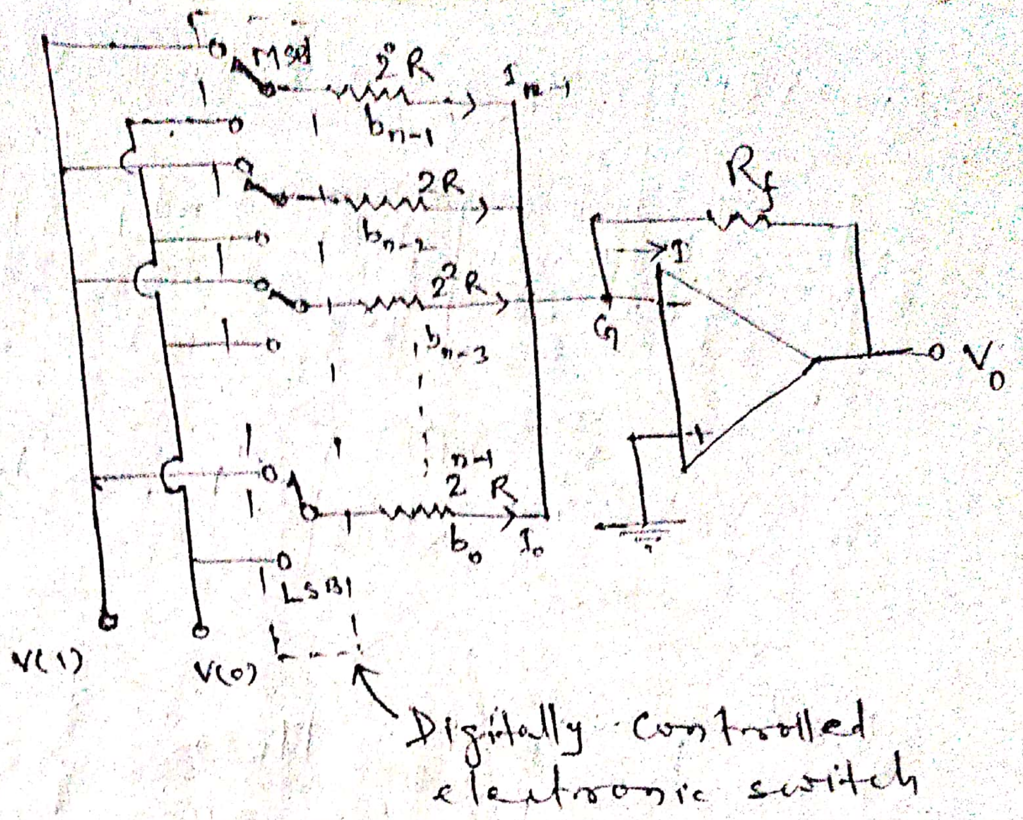
There are various type of D/A converter. Some of them are following—

1) Weighted-Resistor D/A.
2) R-2R ladder type
3) Voltage mode R-2R ladder type
4) Inverted or current mode R-2R ladder type

1) Weighted-Resistor D/A Converter :-

Let, us consider n-bit straight binary input to a resistor network which produces current I corresponding to logic 1 at MSB of n-bit binary, 1/2 corresponding to logic 1 at next lower bit from MSB, $\frac{I}{2^2}$ corresponding to logic 1 at next lower bit, and so on. Finally produces current $\frac{I}{2^{n-1}}$ corresponding to logic 1 at LSB. Thus, we see that ~~total~~ current, thus produced, is proportional to digital input. This current can be converted into a corresponding voltage by using op-amp functioning as current to voltage converter which is proportional to digital input. Such a circuit is shown in fig-1. This ckt is referred to as weighted-resistor D/A converter because, ~~Since~~ the value of resistors are weighted in accordance to binary weights.



Here a digitally controlled switch is used. A voltage V(1) is applied to op-amp inverting terminal when switch logic is at 1 and V(0)=0 is applied which switch logic is 0.

Now, $\cancel{I = I_{n-1} + I_{n-2} + I_{n-3} + \cdots + I_0}$

$$I = I_{n-1} b_{n-1} + I_{n-2} b_{n-2} + I_{n-3} b_{n-3} + \cdots + I_0 b_0$$

or, $$\frac{0 - V_0}{R_f} = \frac{V(1) - 0}{R} b_{n-1} + \frac{V(1) - 0}{2R} b_{n-2} + \frac{V(1) - 0}{2^2 R} b_{n-3} + \cdots + \frac{V(1) - 0}{2^{n-1}} b_0$$

or $$-\frac{V_0}{R_f} = \frac{V(1)}{R}\left[b_{n-1} + \frac{b_{n-2}}{2} + \frac{b_{n-3}}{2^2} + \cdots + \frac{b_0}{2^{n-1}} \right]$$

$$= \frac{V(1)}{R} \cdot \frac{1}{2^{n-1}} \left[2^{n-1} b_{n-1} + 2^{n-2} b_{n-2} + 2^{n-3} b_{n-3} + \cdots + 2^0 b_0 \right]$$

If $V(1) = -V_R$ = Reference voltage then

$$V_0 = -\frac{R_f}{R}\frac{(-V_R)}{2^{n-1}}\left[2^{n-1}b_{n-1} + 2^{n-2}b_{n-2} + \cdots + 2^0 b_0\right]$$

$$\Rightarrow \boxed{V_0 = \frac{V_R}{2^{n-1}}\cdot\frac{R_f}{R}\left[2^{n-1}b_{n-1} + 2^{n-2}b_{n-2} + \cdots + 2^0 b_0\right]}$$

Let, $K = \frac{V_R R_f}{R\, 2^{n-1}}$ then

$$V_0 = K\left(2^{n-1}b_{n-1} + 2^{n-2}b_{n-2} + \cdots + 2^0 b_0\right)$$

i.e Analog output $= K \times$ Digital input

R-2R ladder type D/A converter

A weighted-resistor D/A converter for designing high binary bit D/A converter, we need wide range of resistor (as multiple of 2^n) which is in practice not a convenient process. For, this or to avoid this problem, we design R-2R ladder type D/A converter. R-2R ladder type D/A converter uses only two types of resistor as R and 2R which is most suited for Integrated ckt (IC) fabrication.

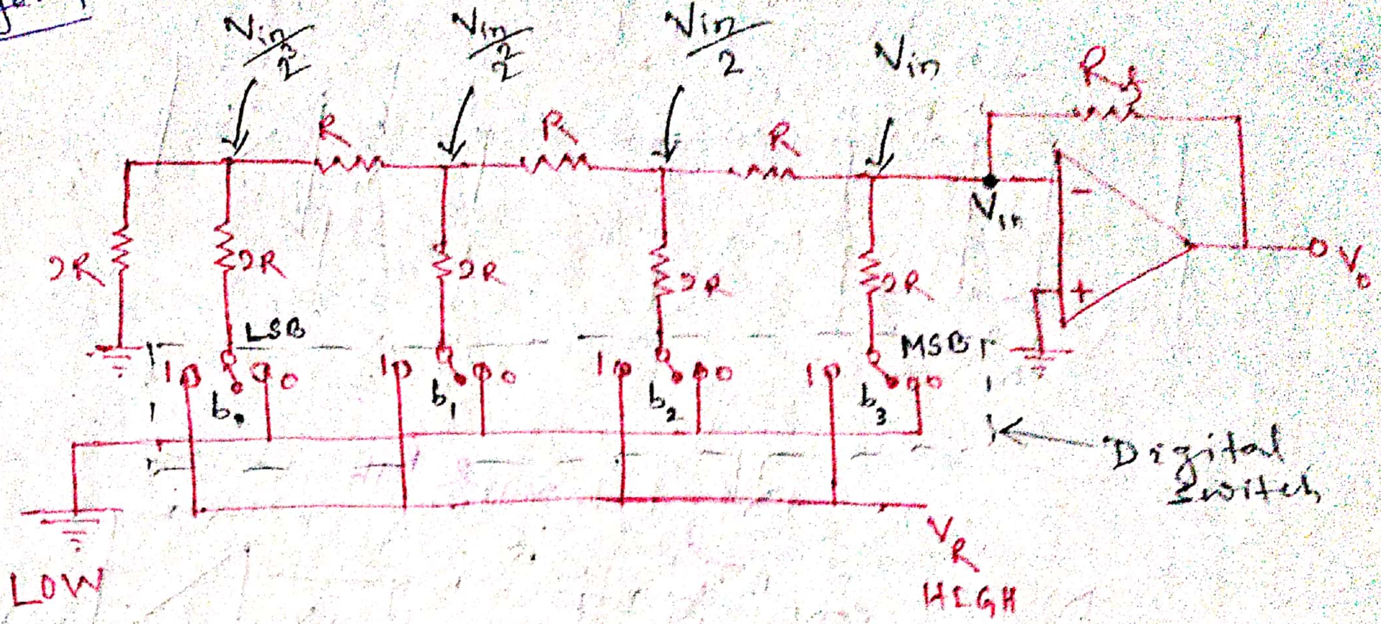


Fig-1.

A 4-bit R-2R ladder type D/A converter is shown in fig-1. Here four binary bits are $b_3b_2b_1b_0$ in which b_3 is MSB and b_0 is LSB. In this condition, the output voltage is weighted sum of digital inputs which is performed by an operational amplifier with feedback resistor R_f. The analysis can be done in better way by following cases.

Case:-I. Let, $b_3b_2b_1b_0 = 0001$.

i.e. A reference voltage is applied only to the LSB bit b_0. In this case, the ckt can be modified as in fig-2.

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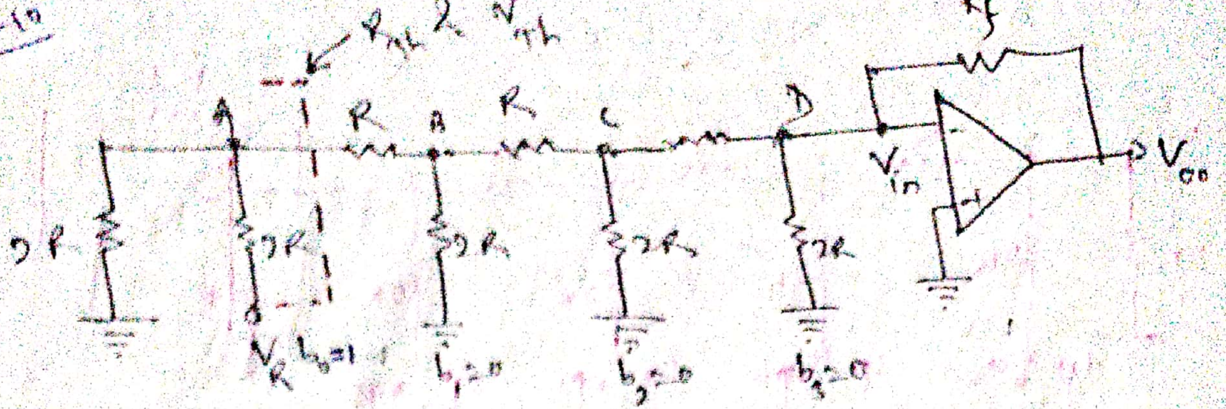

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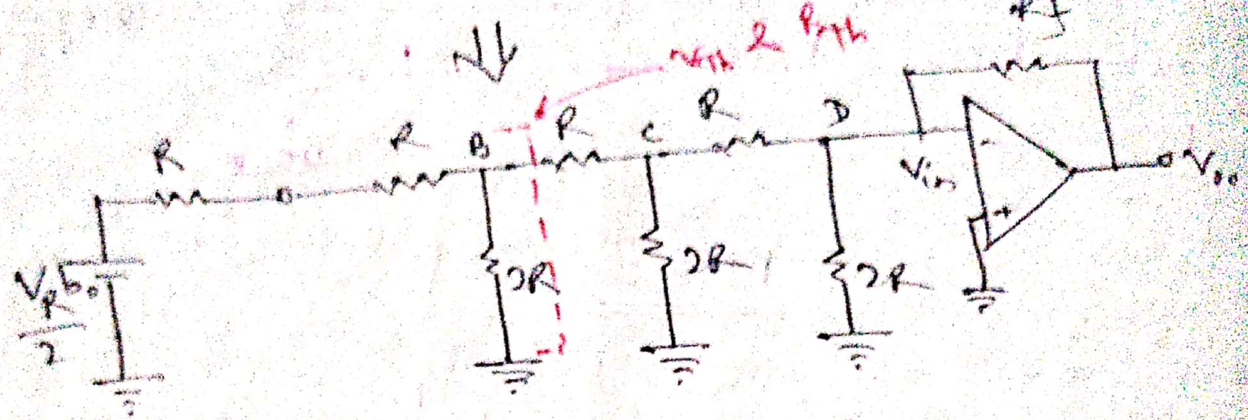

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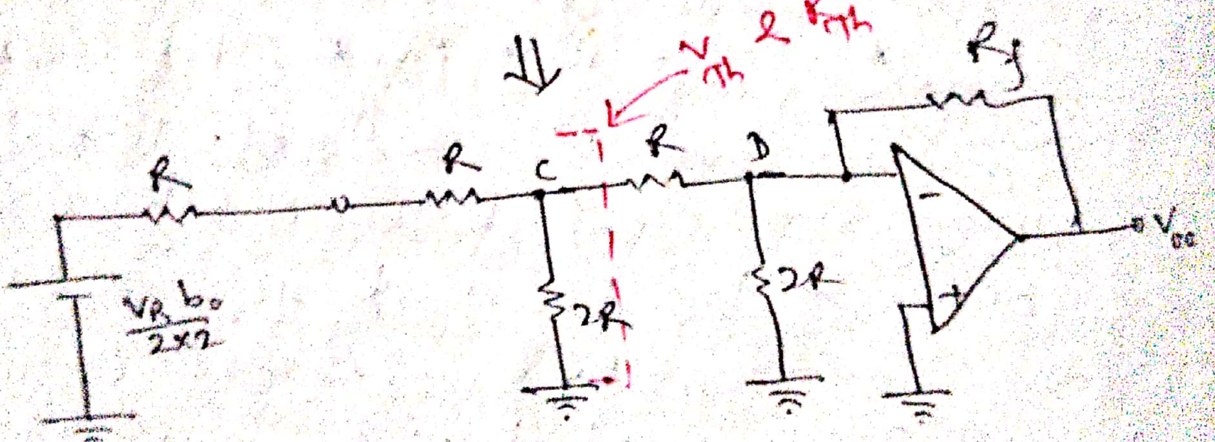

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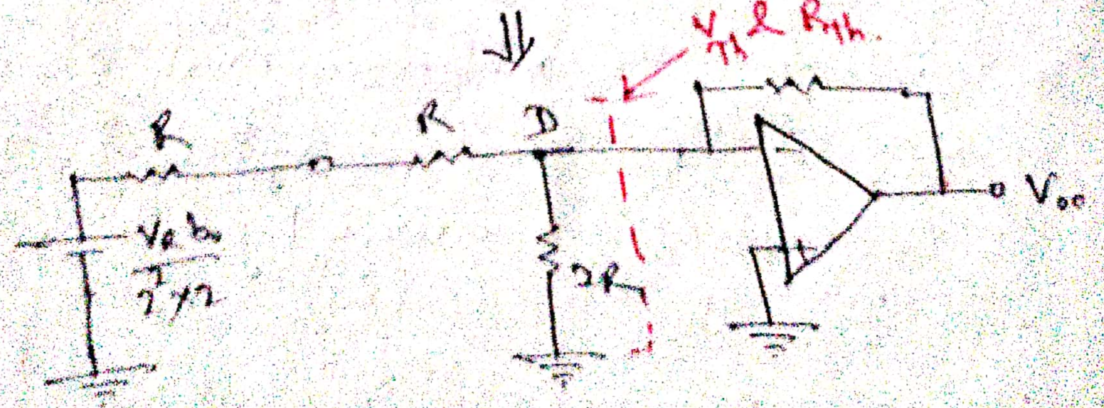

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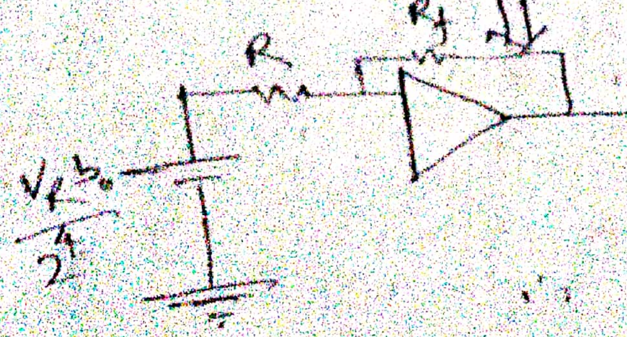

$$\therefore V_{00} = -\frac{R_f}{R}\cdot\frac{V_R b_0}{2^4}$$

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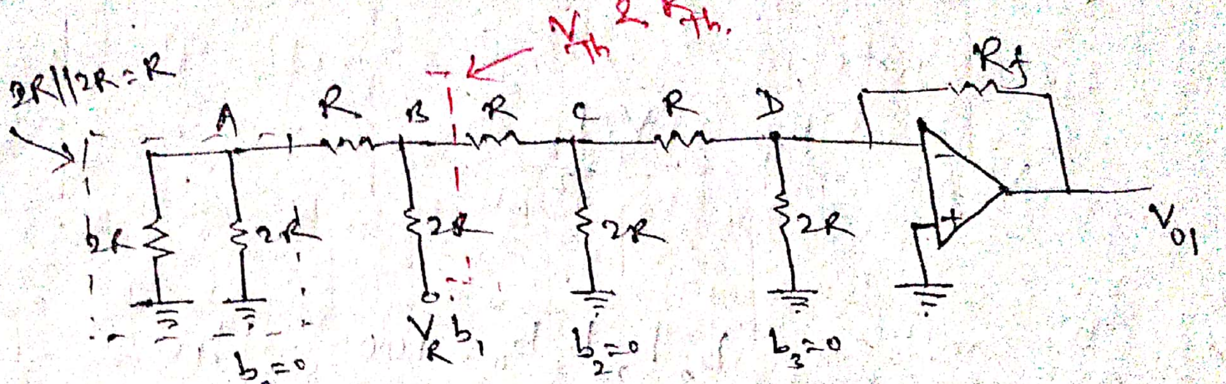
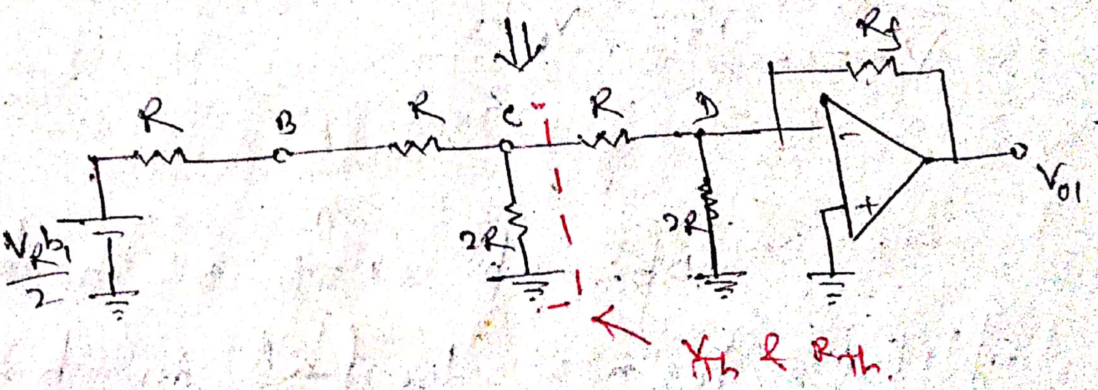
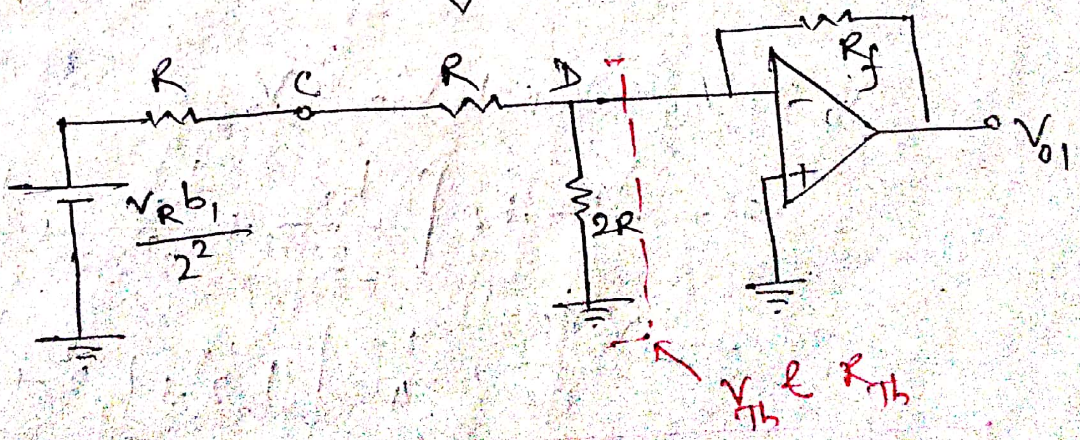
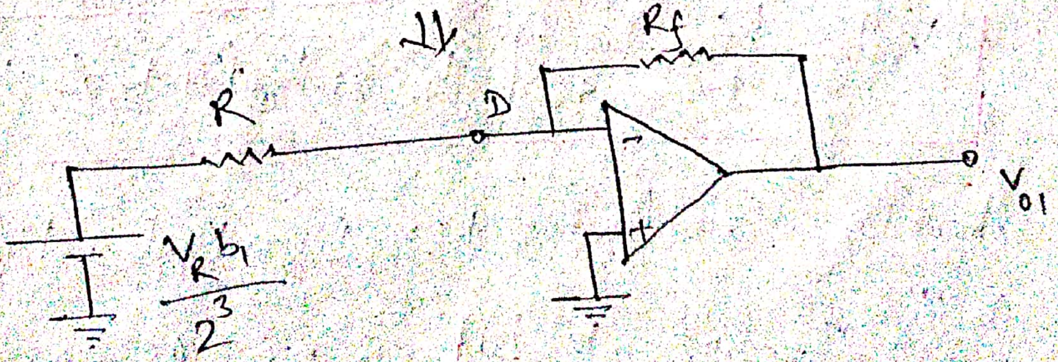
Case:-II. When, $b_3 b_2 b_1 b_0 = 0010$ then ckt becomes ____









$$\therefore V_{01} = -\frac{R_f}{R} \cdot \frac{V_R b_1}{2^3}$$

Case:- III. When, $b_3 b_2 b_1 b_0 = 0100$, then as discussed in case-I & II, we can calculate,

$$V_{02} = -\frac{R_f}{R} \cdot \frac{V_R b_2}{2^2}$$

Case:- IV. When, $b_3 b_2 b_1 b_0 = 1000$ then

$$V_{03} = -\frac{R_f}{R} \cdot \frac{V_R b_3}{2}$$

Since op-amp acts as here summ amplifier, hence total output is given by —

$$V_0 = V_{00} + V_{01} + V_{02} + V_{03}$$

$$= -\frac{V_R}{R} \cdot R_f \left[\frac{b_3}{2} + \frac{b_2}{2^2} + \frac{b_1}{2^3} + \frac{b_0}{2^4} \right]$$

$$= -\frac{V_R R_f}{R} \cdot \frac{1}{2^4} \left[b_3 2^3 + b_2 2^2 + b_1 2^1 + b_0 2^0 \right]$$

$$\therefore \boxed{|V_0| = \frac{R_f}{R} \cdot \frac{V_R}{2^4} \left[b_3 2^3 + b_2 2^2 + b_1 2^1 + b_0 2^0 \right]}$$

Analog output = k × Digital input.

Similarly, for n-bit R-2R ladder type D/A converter, we can show that

$$\boxed{V_0 = \frac{R_f}{R} \cdot \frac{V_R}{2^n} \left[b_{n-1} 2^{n-1} + b_{n-2} 2^{n-2} + \dots + b_0 2^0 \right]}$$

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$$V_0 = \frac{R_f}{R} \cdot \frac{V_R}{2^n}\left[b_{n-1} 2^{n-1} + b_{n-2} 2^{n-2} + \cdots + b_0 2^0\right]$$

if $R_f = R$ then

$$V_0 = \frac{b_{n-1} 2^{n-1} + b_{n-2} 2^{n-2} + \cdots + b_1 2 + b_0 2^0}{2^n} \times V_R$$

The Resolution of R-2R ladder type D/A converter is given by—

Resolution $\boxed{I = \frac{V_0}{R_f} = \frac{1}{2^n} \cdot \frac{V_R}{R}}$

Resolution $V = \frac{1}{2^n} \cdot \frac{R_f}{R} \times V_R$

if $R = R_f$ then—

$$\boxed{\text{Resolution} = \frac{1}{2^n} \times V_R}$$

Note:- For, non-inverting op-amp configuration—

$$V_0 = \frac{V_R}{2^n}\left(1 + \frac{R_f}{R_1}\right)\left[b_{n-1} 2^{n-1} + b_{n-2} 2^{n-2} + \cdots + b_0 2^0\right]$$