R-2R LADDER TYPE DAC (4-Bit)

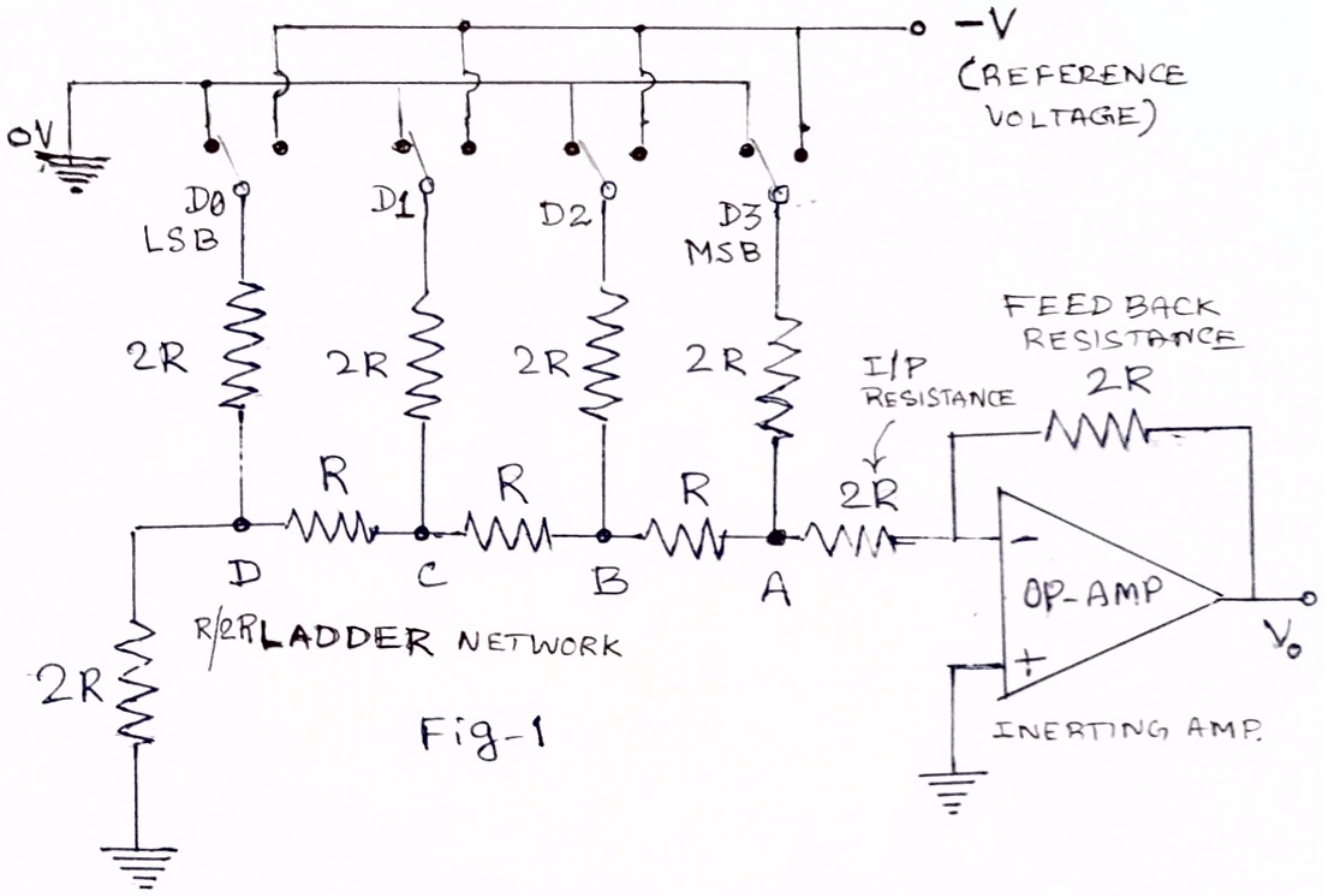


Fig-1

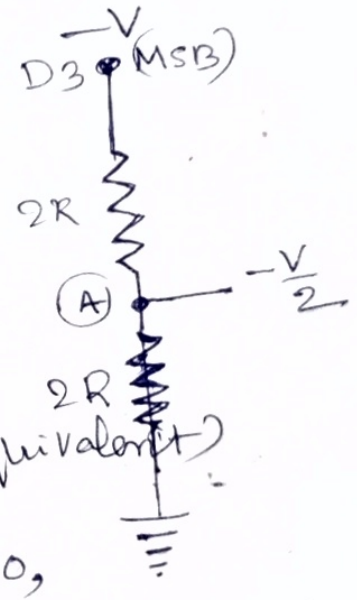
The R-2R Ladder type DAC consists of only two resistances R and 2R and an op-Amp. It can be shown that resistance between any node A/B/C/D and ground is 2R. D3 D2 D1 D0 are digital inputs. It can be either at logic 0 (zero volts) or logic 1 (-V volts) where -V is the reference voltage. The 4-bit DAC required 4 stage Ladder network. A, B, C & D are different nodes of the Ladder. D3 is the MSB and D0 is the LSB. The op-Amp is connected

in the inverting configuration with input resistance 2R and feedback resistance 2R. ie: gain = −1. It can be proved that the voltage at node A is the weighted sum of inputs present at the terminals $D_3\ D_2\ D_1\ D_0$.

Case-1: Let $D_3\ D_2\ D_1\ D_0 = 1000$, MSB alone is 1, other bits are 0. In that case the circuit can be reduced as shown in Fig 2.

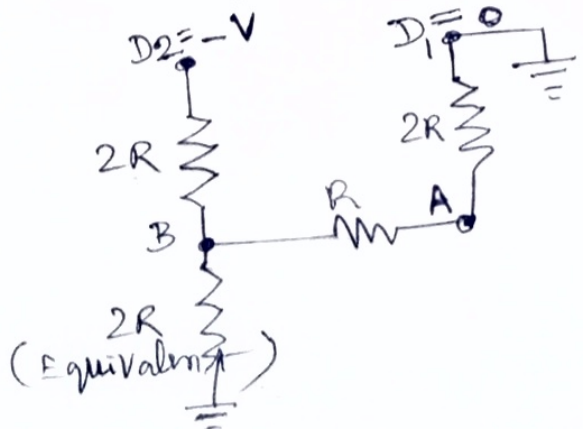
The voltage at node A is

$$V_A = \frac{-V}{2}$$



Case-2:

Let $D_3\ D_2\ D_1\ D_0 = 0100$, Next D_2 is 1, the other bits are 0. In that case, the Ladder network is reduced as shown in Fig 3



The parallel resistance between B and ground is

$$R_{11} = \frac{2R \cdot 3R}{2R+3R} = \frac{6R^2}{5R} = \frac{6R}{5}$$

Total resistance between D_2 and ground is

$$R_T = \frac{6R}{5} + 2R = \frac{16R}{5}$$

current flowing from D_2 to ground:

$$I_{D2} = \frac{-V}{\left(\frac{16R}{5}\right)} = \frac{-5V}{16R}$$

Voltage at node B:

$$V_B = \frac{-5V}{16R} \times \frac{16R}{5} \times 3 = -3V$$

Voltage at node A:

$$V_A = \frac{V_B}{3R} \times 2R = +\frac{V_B \cdot 2}{3} = \frac{-3V \cdot 2}{3}$$

$$V_A = -\frac{V}{4}$$

Illy it can be proved for other digital inputs as shown:

D3	D2	D1	D0	V_A
1	0	0	0	$-\frac{V}{2}$
0	1	0	0	$-V/4$
0	0	1	0	$-V/8$
0	0	0	1	$-V/16$

From this idea, the output for different combinations of digital input is shown in the next table:

When reference voltage is $-16V$, the output values are noted in the table.

Digital Inputs				Analog output
D_3	D_2	D_1	D_0	V_o VOLTS
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9
1	0	1	0	10
1	0	1	1	11
1	1	0	0	12
1	1	0	1	13
1	1	1	0	14
1	1	1	1	15