Digital to Analog Converters

max → 1V

$\frac{1}{16} =$

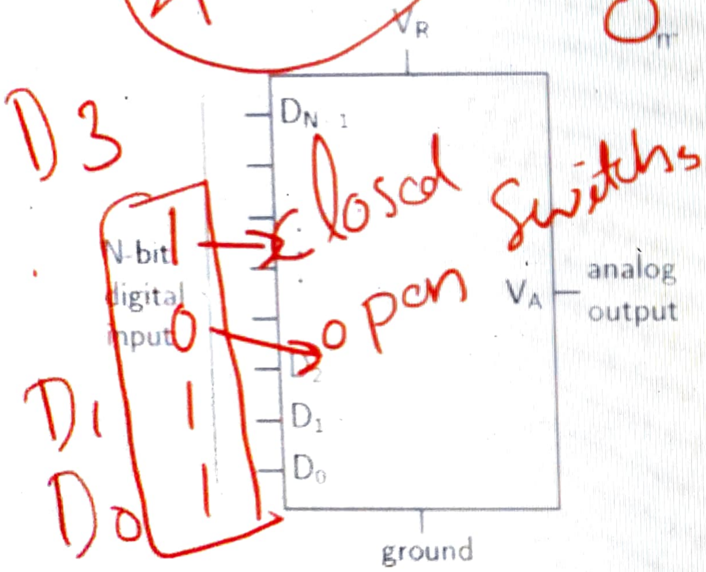
4-bit

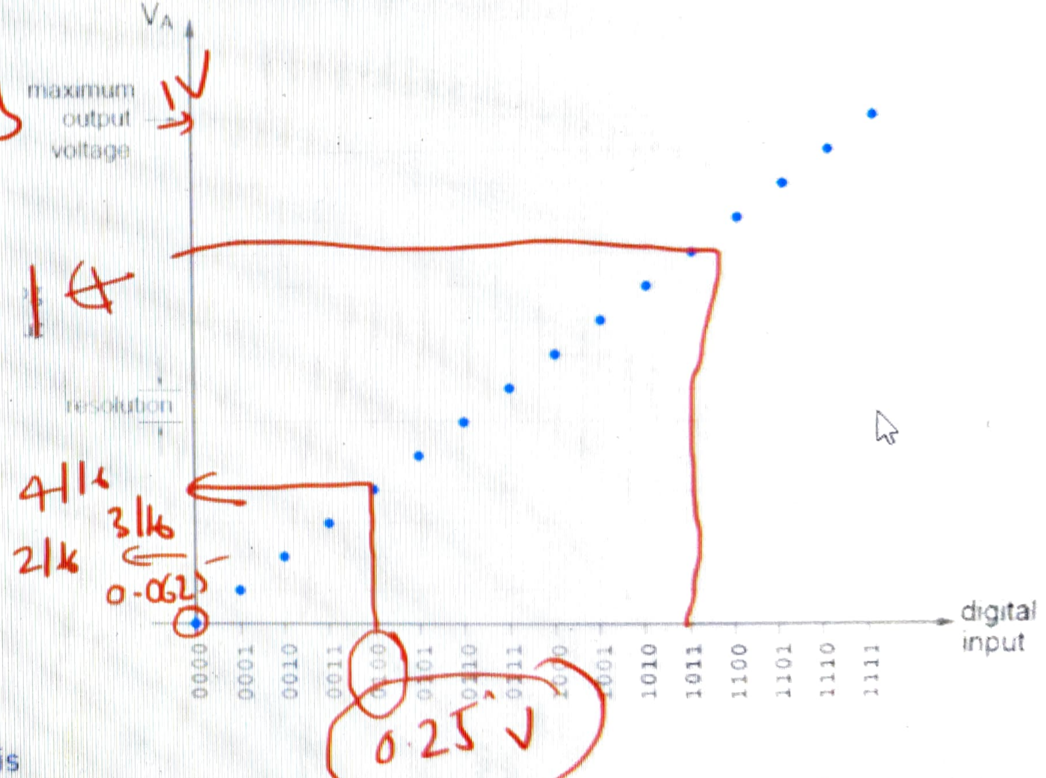
$D_3 D_2 D_1 D_0$ 0F

0 0 0 0

switches 16 comb

1 1 1 1 F

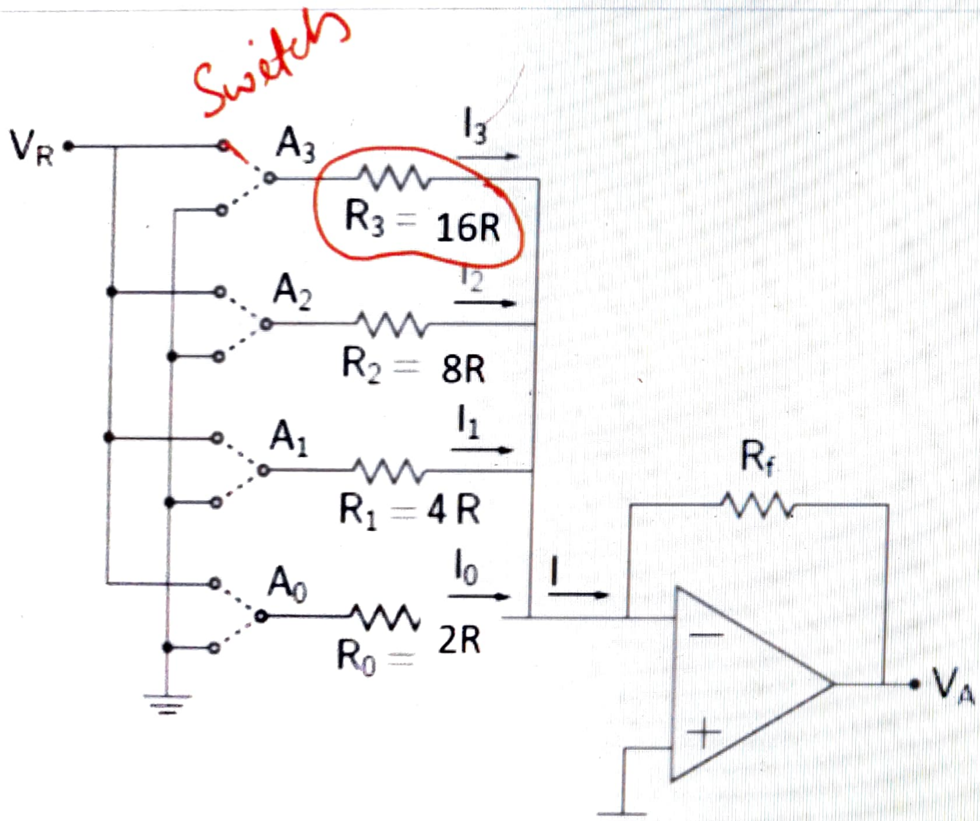




For a 4-bit DAC, with input $S_3S_2S_1S_0$, the output voltage is
$V_A = K\,[(S_3 \times 2^3) + (S_2 \times 2^2) + (S_1 \times 2^1) + (S_0 \times 2^0)]$.
In general, $V_A = K \sum_0^{N-1} S_k 2^k$.

K is proportional to the reference voltage V_R. Its value depends on how the DAC is implemented.

DAC using Binary-weighted resistors



$$I = I_0 + I_1 + I_2 + I_3$$

- It consists of parallel binary weighted resistor bank and a feedback resistor Rf.
- The switch positions decides the binary word (i.e. A_0, A_1, ...A_n).
- In the circuit op-amp is used as current to voltage converter.

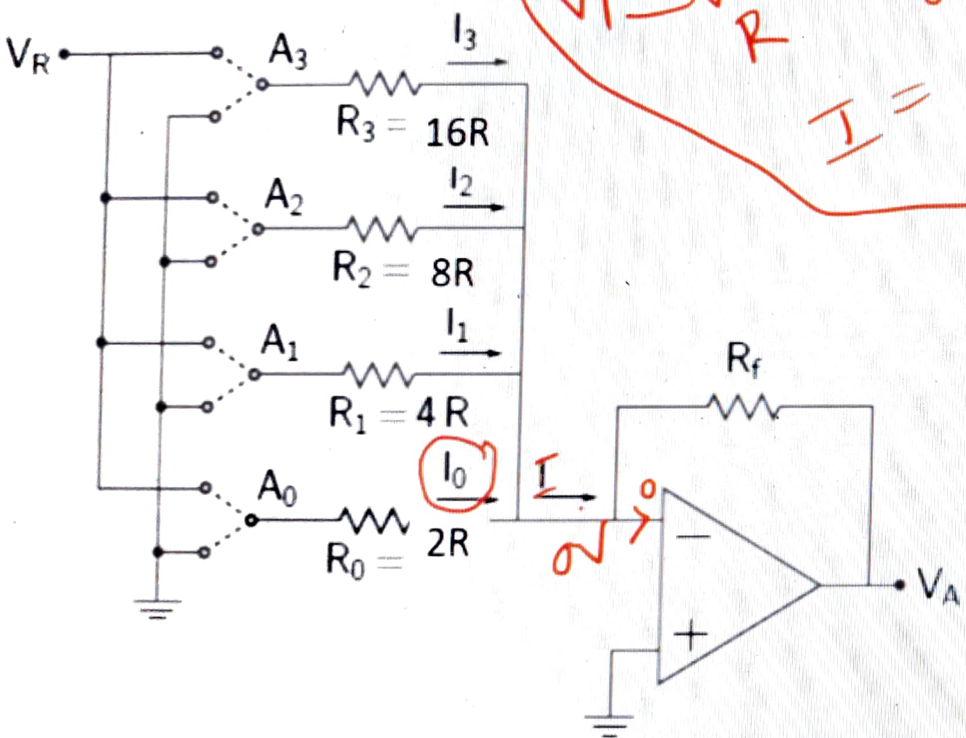
$$I_0 = \frac{A_o V_R}{R_o}$$

$$I_1 = \frac{A_1 V_R}{R_1}$$

DAC using Binary-weighted resistors

$V_1 \xrightarrow{R} 0V$

$I = \frac{V_1}{R}$



$$I = I_0 + I_1 + I_2 + I_3$$

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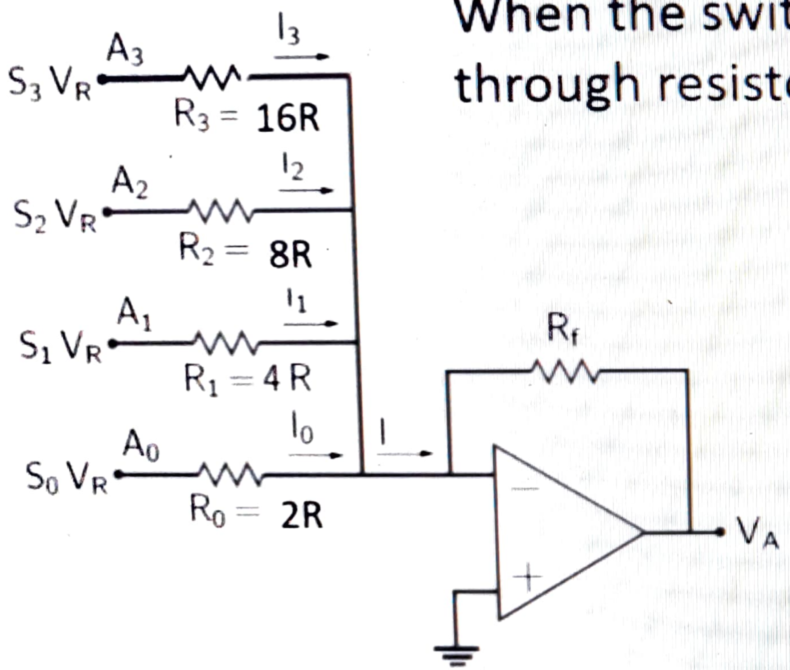
0 1

$$I_0 = \frac{A_0 V_R}{R_0} = 0 \qquad \frac{V_R}{R_0}$$

$$I_1 = \frac{A_1 V_R}{R_1} \qquad I_2, I_3$$

DAC using Binary-weighted resistors



When the switches are closed the respective currents are flowing through resistors as shown in the circuit diagram

$$\therefore V_o = -IR_f$$

$$\therefore V_o = -[I_1 + I_2 + I_3 + \ldots\ldots\ldots\ldots + I_n] R_f$$

$$\therefore V_o = -\left[S_0 \frac{V_R}{2^1 R} + S_1 \frac{V_R}{2^2 R} + S_2 \frac{V_R}{2^3 R} + \ldots\ldots + S_n \frac{V_R}{2^n R} \right] R_f$$

$$V_o = -\frac{R_f}{R} V_R [S_0\ 2^{-1} + S_1\ 2^{-2} + S_2\ .2^{-3} + \ldots\ldots + S_2\ .2^{-n}]$$

$$If\ R_f = R$$

$$\therefore V_o = -V_R [S_0\ .2^{-1} + S_1\ .2^{-2} + S_2\ ..2^{-3} + \ldots\ldots + S_2\ .2^{-n}]$$

Problems

- Consider the example of 3-bit DAC. When input binary sequence is $A_0A_1A_2 = 001$
- Consider the example of 3-bit DAC. When input binary sequence is $A_0A_1A_2 = 101$