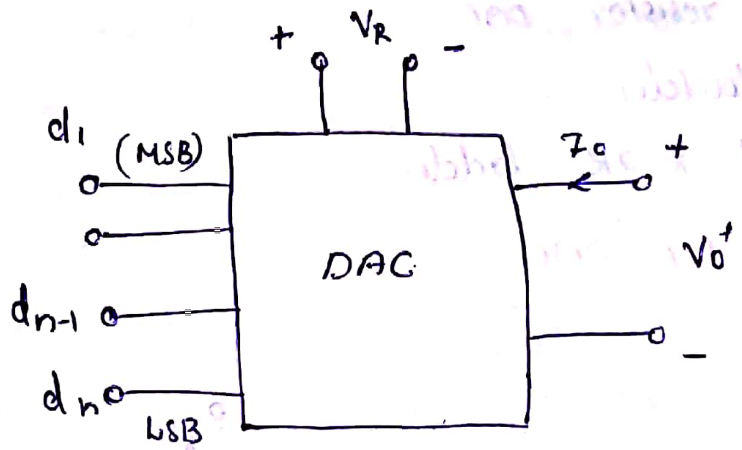
Basic DAC Techniques



Schematic of a DAC.

The input is an n-bit binary word D and is combined with a reference voltage V_R to give an analog output signal. The output of DAC can be either a voltage or current. For a voltage output DAC, the D/A converter is mathematically described as

$$V_o = K V_{FS} \left(d_1 2^{-1} + d_2 2^{-2} + \dots + d_n 2^{-n} \right)$$

where V_o = output voltage.

V_{FS} = Full scale output voltage.

K — scaling factor usually adjusted to unity

$d_1, d_2 \dots d_n \rightarrow$ n-bit binary fractional word with the decimal point located at the left.

$d_1 \rightarrow$ Most significant bit (MSB) with a weight of $V_{FS}/2$.

$d_n \rightarrow$ Least significant bit (LSB) with a weight of $V_{FS}/2^n$.

The different DAC techniques are

* weighted resistor DAC
* R-2R ladder
* Inverted R-2R ladder

Q. The basic step of a 9-bit DAC is 10.3 mV. If 000000000 represents 0V, what output is produced if the input is 101101111.

Solution

The output voltage for input 101101111 is

$= 10.3\ \text{mV}\ (1 \times 2^8 + 0 \times 2^7 + 1 \times 2^6 + 1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0)$

$= 10.3\ \text{mV}\ (367) = 3.78\ \text{V}$

Example 10.2

Calculate the values of the LSB, MSB and full scale output for an 8-bit DAC for the 0 to 10 V range.

Solution

$$\text{LSB} = \frac{1}{2^8} = \frac{1}{256}$$

For 10 V range, $\text{LSB} = \dfrac{10\ \text{V}}{256} = 39\ \text{mV}$

and $\text{MSB} = \left(\dfrac{1}{2}\right)$ full scale $= 5\ \text{V}$

Full scale output = (Full scale voltage − 1 LSB)

$= 10\ \text{V} - 0.039\ \text{V} = 9.961\ \text{V}$

Example 10.3

What output voltage would be produced by a D/A converter whose output range is 0 to 10 V and whose input binary number is

(i) 10 (for a 2-bit D/A converter)
(ii) 0110 (for a 4-bit DAC)
(iii) 10111100 (for a 8-bit DAC)

Solution

(i) $V_o = 10\ \text{V}\left(1 \times \dfrac{1}{2} + 0 \times \dfrac{1}{4}\right) = 5\ \text{V}$

(ii) $V_o = 10\ \text{V}\left(0 \times \dfrac{1}{2} + 1 \times \dfrac{1}{2^2} + 1 \times \dfrac{1}{2^3} + 0 \times \dfrac{1}{2^4}\right)$

$= 10\left(\dfrac{1}{4} + \dfrac{1}{8}\right) = 3.75\ \text{V}$

(iii) $V_o = 10\ \text{V}\ (1 \times 1/2 + 0 \times 1/2^2 + 1 \times 1/2^3 + 1 \times 1/2^4 + 1 \times 1/2^5 + 1 \times 1/2^6 + 0 \times 1/2^7 + 0 \times 1/2^8)$

$= 10\ \text{V}\ (1/2 + 1/8 + 1/16 + 1/32 + 1/64) = 7.34\ \text{V}$