D/A and A/D

D/A :- A device that converts the digital data (binary input) into equivalent analog data is called Digital-to-Analog converter. The analog data is required to drive motor or analog devices.

Some specification of D/A.

Accuracy :- Absolute accuracy defines the maximum deviation of the output from the ideal value and it is expressed in fraction of LSB.

Offset voltage :- Ideally, the output of D/A should be zero volt (0 volt) but in practice when all the input binary bits are zero, there is a small output voltage. such an output voltage is called offset voltage or offset error. The offset error is nullified by translating the actual A/D converter characteristic up or down as illustrated in fig-1.(a) & (b)

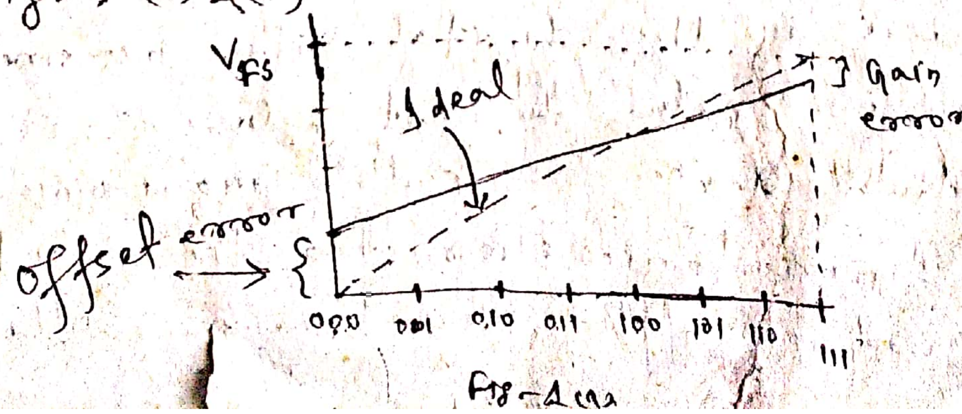


Fig-1 (a)

Linearity :→ Linearity is discussed in terms of linearity error. Linearity error is defined as the maximum deviation in step size from the ideal step size. It is most common dynamic error. An ideal D/A converter produces equal increment in analog output for equal increments in digital input.

However, due to gain error and offset error which is due to resistors, produces some non-linearity which is illustrated in transfer characteristic as shown in fig-2. by solid line

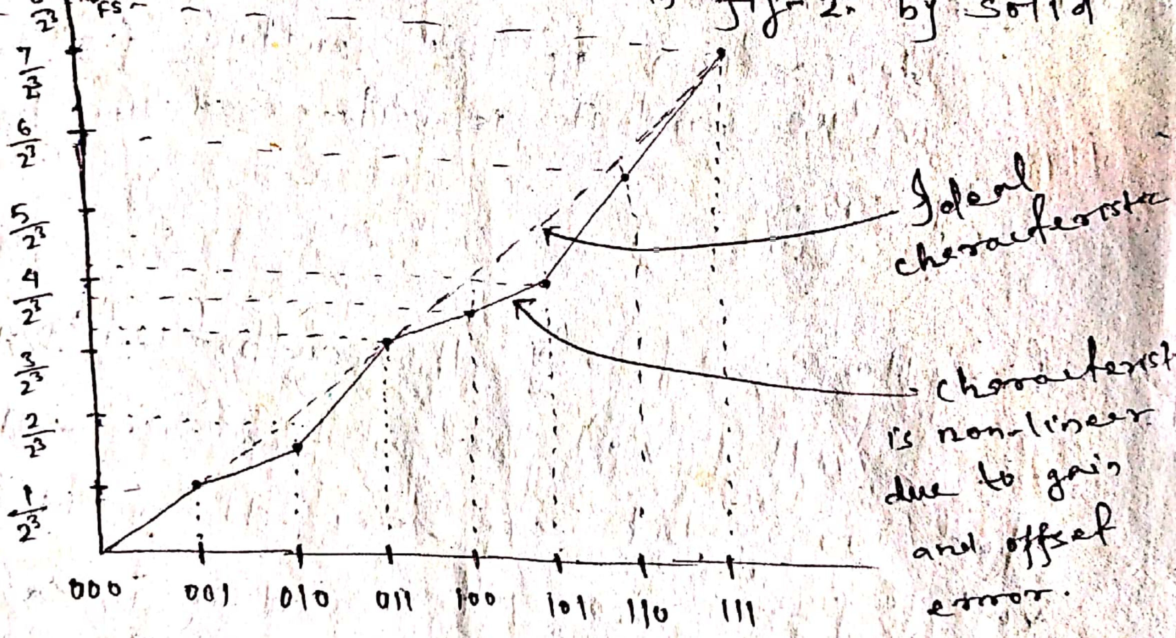


fig-2

Monotonicity :→ Monotonicity of D/A is the characteristic which illustrate that the output increases as the digital input incremented from one value to next value. If, it is so, then device is called monotonic.
The monotonic characteristic is important in control application because without

this characteristic, oscillation will result. ~~An~~ A D/A converter is identified as monotic if linearity error be less than $\pm \frac{1}{2}$ (LSB) at each output level.

Resolution (or step size):- Resolution of D/A converter is defined as the smallest change that occur in output as a result due to corresponding change in digital input. "Resolution is always equal to the weight of LSB and is also referred to as step-size" because it is the amount ~~of~~ that V_{out} will change as the digital input change from one step to next step. It can be understand in better way by following example.

Let, there is a 4-bit D/A converter which output is supplied from 4-bit counter as shown —

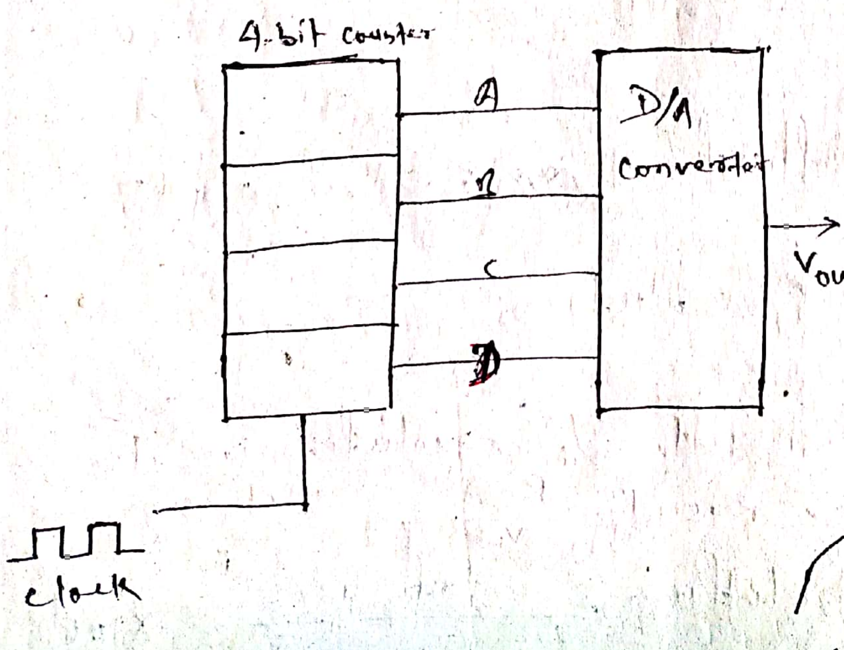


Fig-3.

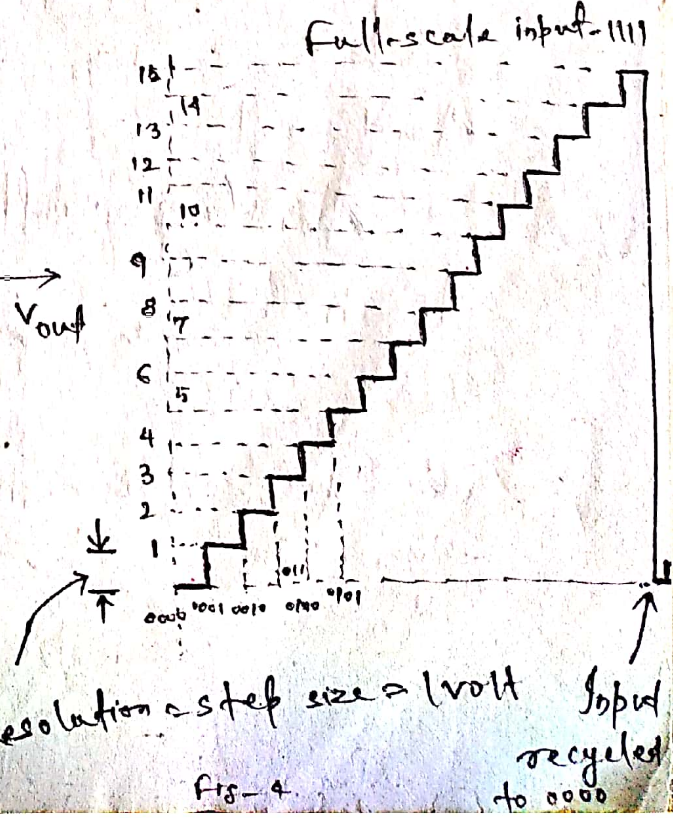


Fig-4.

Here from fig-2 represents that output of D/A is not ideal or perfect analog quantity but staircase waveform in such a way that output voltage goes up 1 volt per step as the input to D/A converter goes from one digital level to the next. Here when input is 1111 then output of D/A converter is 15 volt. This is the maximum value of analog output and is called full-scale output V_{FS}. Here there is a point to be noted that there are 16-levels starting from 0 to 15 but 15 jumps or steps. Thus for n-bit D/A converter, there will be 2^n levels and (2^n-1) steps. Therefore mathematically

$$\boxed{\text{Resolution} = \frac{A_{fs}}{2^n-1} = \frac{V_{FS}}{2^n-1} = \text{step size}}$$

And,

Analog output = K × Digital input

where,

K = Resolution

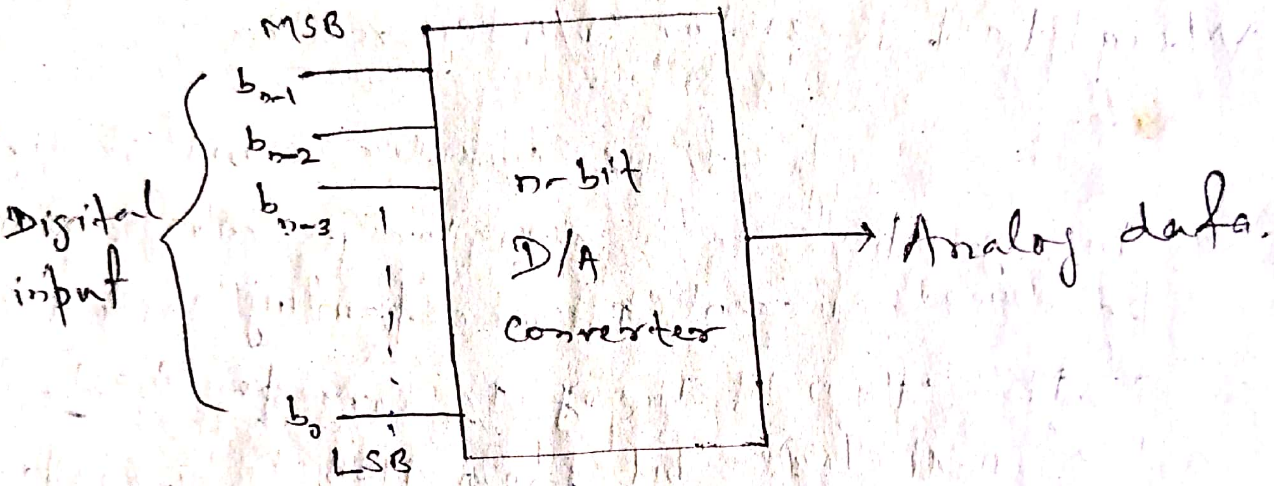
On the other hand, % resolution is also given by —— $\% \text{ Resoul}^n = \frac{\text{Resol}^n}{V_{FS}} = \frac{\text{step-size}}{V_{FS}}$

$$\% \text{ Resolution} = \frac{\text{step size}}{\cancel{\text{Total no. of steps}}\ \text{Full-scale}} \times 100.$$

$$\Rightarrow \boxed{\% \text{ Resol}^n = \frac{1}{2^n-1} = \frac{\text{Resol}^n}{A_{fs}}}$$

BASIC D/A Conversion Technique

D/A converter accept digital input i.e binary code and produces analog output. A basic block diagram for n-bit D/A is shown in fig-(a) as below —



Here the output analog data is proportional to the digital input and mathematically related as —

$$\text{Analog o/p} = K \times \text{Digital input}$$

$$K = \text{Constant (Resolution)}$$

$$V_0 = K\left(2^{n-1} b_{n-1} + 2^{n-2} b_{n-2} + 2^{n-3} b_{n-3} + \cdots + 2^0 b_0\right)$$

Here b_0 = LSB bit

b_{n-1} = MSB bit.