Data Conversion Chain — 20-02-2017

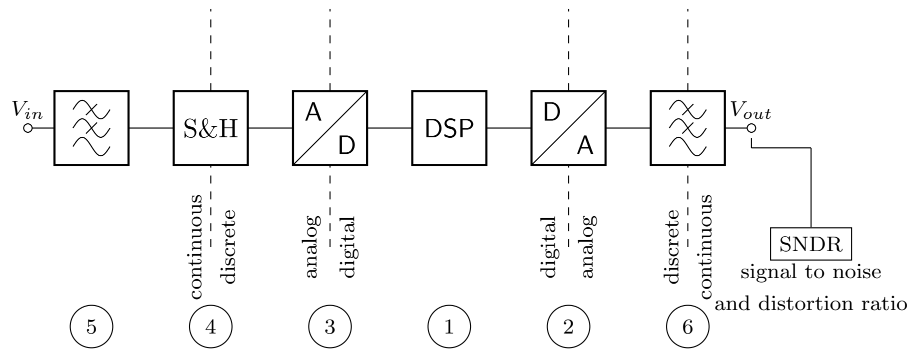


Figure 1: A typical signal chain

(1) DSP

The equivalent ouput voltage can be expressed with 1. It's maximum can be described with 2

$$V_{eq} = V_{ref}\left(\sum_{i=1}^{N} b_i 2^{-i}\right) \tag{1}$$

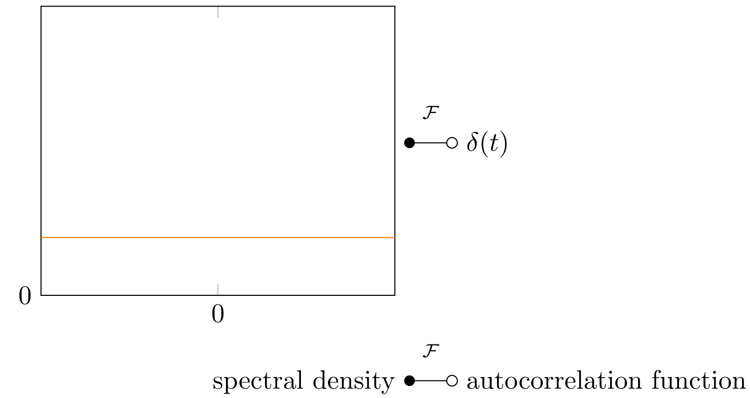
$$V_{eq} = V_{ref}\left(1 - 2^{-N}\right) \tag{2}$$

This is a representation in UINT. In most realworld impelemntations INT using 2's complement is required. Sometimes if there is peak currents, Gray-Code is to be used to minimize peak currents!

The quantizer-error is defined with equation 3.

$$V_e = V_{in} - V_{eq} \tag{3}$$

It is assumed that the error behaves like white noise[1] because the digital signal is a sequence of pulses. If this is fourier transformed a constant spectral density is received.



Since the quantizer error has the probability density function of white noise, it can be depicted with the function seen in 2.

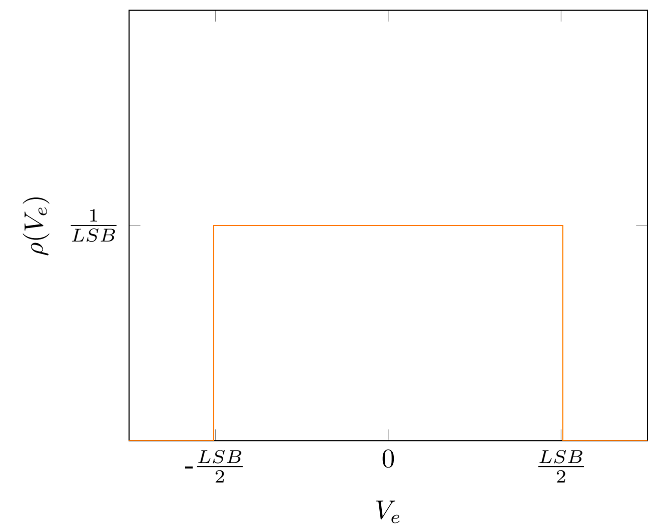


Figure 2: Probability density function of the quatizer error

With the knowledge of the fact that the variance equals the RMS[2] value, depicted in equation 4 and thus 8, we can now find the SNR[3] value with solving equation 11

$$(rms)^2 = \sigma,\ \sigma \text{ is the standard deviation} \tag{4}$$

[1] White noise means that the noise has the same amplitude for every frequency.
[2] root mean square
[3] signal to noise ratio

$$\sigma_e^2 = \int_{-\infty}^{+\infty} V_e^2 \rho(V_e) dV_e \tag{5}$$
$$= \int_{-\frac{LSB}{2}}^{+\frac{LSB}{2}} \frac{V_e^2}{LSB} dV_e \tag{6}$$
$$= \frac{1}{LSB}\frac{1}{3} V_e^3 \Big|_{-\frac{LSB}{2}}^{+\frac{LSB}{2}} \tag{7}$$
$$= \frac{LSB^2}{12} = \frac{1}{12} V_{ref}^2 2^{-2N} \tag{8}$$

$$SNR = \frac{V_{sig,rms}^2}{V_{n,rms}^2} \tag{9}$$
$$= \frac{\left(\frac{V_ref}{2}\frac{1}{\sqrt{2}}\right)^2}{\frac{1}{12} V_{ref}^2 2^{-2N}} \tag{10}$$
$$= N \cdot 6.02dB + 1.76dB \tag{11}$$

Using this equation a statement about the ENOB[4] can be made, having a look at the SNR equation optained. This is given in 12.

$$N_{eff} = ENOB = \frac{SNDR - 1.76dB}{6.02dB} \tag{12}$$

2 D/A

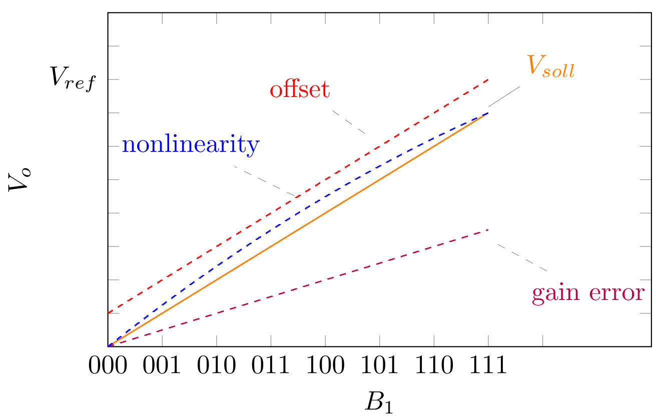


Figure 3: Output of a DAC and possible errors

There is two kinds of nonlinearities:

- INL: integral nonlinearity: $V_{soll} - V_{ist}$
- DNL: differential nonlinearity: $\Delta V_{soll} - \Delta V_{ist}$

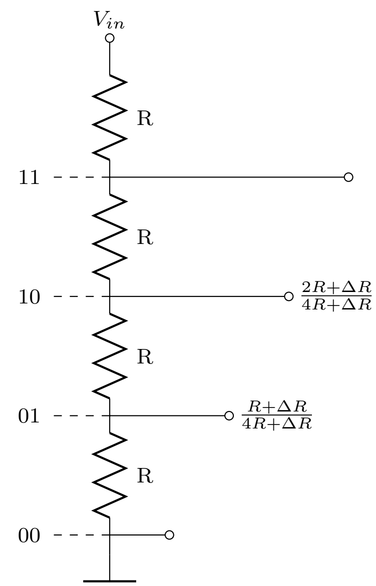


Figure 4: Resistor ladder to implement a dac

In figure 4 the DNL can be calculated as given in equation 15.

$$\Delta V_{ist} = \frac{R + \Delta R}{2^N R + \Delta R} \tag{13}$$
$$\Delta V_{soll} = \frac{R}{2^N R} \tag{14}$$
$$\frac{\Delta R}{2^N R} V_{ref} = \frac{\Delta R}{R} [LSB] \tag{15}$$

A DAC has monotone behavior if $DNL \in [-1, 1]$, which means that a higher B_1 always results in a higher V_o. If a DAC has "no missing codes" guaranteed, all digital values result in a different V_o. So no digital value will ever be skipped.

3 A/D

4 S&H

5 6 LP

[4] effective number of bits