Data Conversion Chain — 20-02-2017

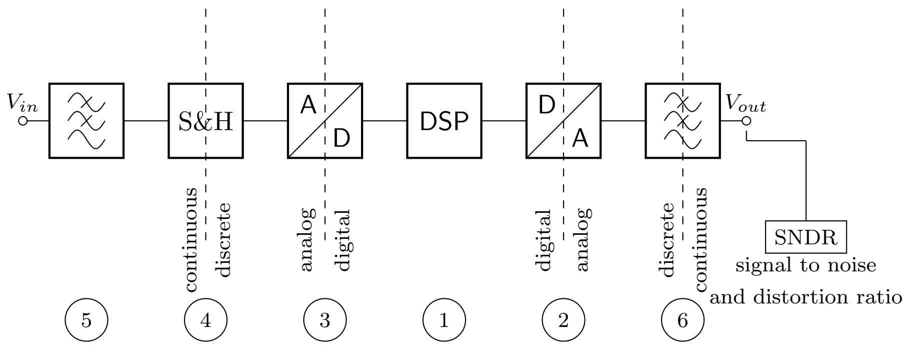


Figure 1: A typical signal chain

1 DSP

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

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

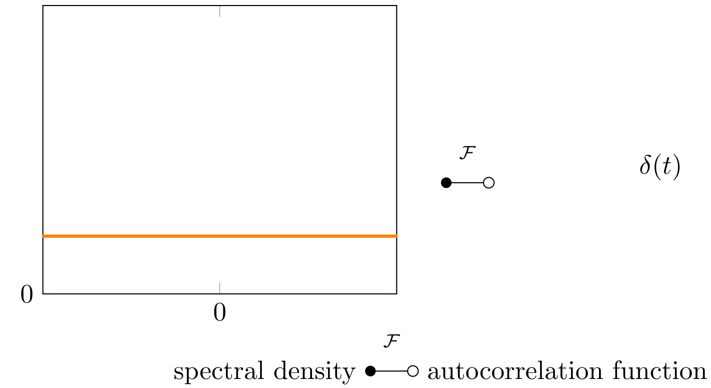
$$V_{eq} = V_{ref}\Big(1 - 2^{-N}\Big) \tag{2}$$

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.

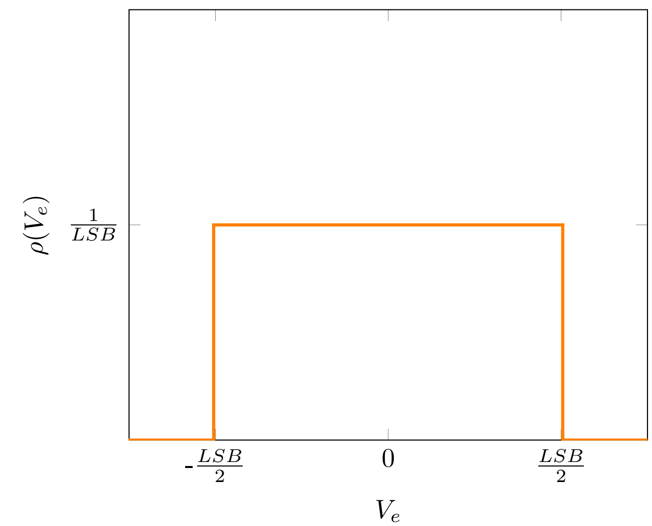


Figure 2: Probability density function of the quatizer error

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
[4] effective number of bits

$$\sigma_e^2 = \int_{-\infty}^{+\infty} V_e^2 \rho(V_e) dV_e \tag{5}$$

$$= \int_{-\frac{LSB}{2}}^{+\frac{LSB}{2}} \frac{V_e^2}{LSB} dV_e \tag{6}$$

$$= \frac{1}{LSB} \frac{1}{3} V_e^3 \Big|_{-\frac{LSB}{2}}^{+\frac{LSB}{2}} \tag{7}$$

$$= \frac{LSB^2}{12} = \frac{1}{12} V_{ref}^2 2^{-2N} \tag{8}$$

$$SNR = \frac{V_{sig,rms}^2}{V_{n,rms}^2} \tag{9}$$

$$= \frac{\left(\frac{V_{ref}}{2}\frac{1}{\sqrt{2}}\right)^2}{\frac{1}{12} V_{ref}^2 2^{-2N}} \tag{10}$$

$$= N \cdot 6.02dB + 1.76dB \tag{11}$$

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

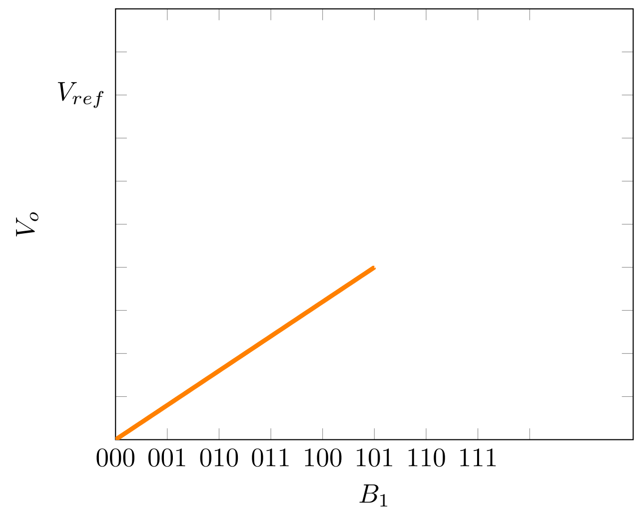


Figure 3: Output of a DAC and possible errors

3 A/D

4 S&H

5 6 LP