EE 521: Instrumentation and Measurements

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Nyquist Sampling Theorem

- Theoretically, to avoid aliasing a continuous signal must be sampled at least twice the maximum frequency.
- Just twice the maximum frequency requires ideal filters, therefore in practice need to sample more than twice the maximum frequency.
- Use antialiasing filter to avoid aliasing. Investigate the specification of the antialiasing filter present in the device to determine the proper sampling frequency.

Source of Quantization Error

- In order to represent digital signals, after sampling the continuous signal must be quantized to a finite number of bits resulting in *quantization error*.
- Given a maximum peak-to-peak voltage V_{max}, the step size Δ between levels is given by

$$\Delta = \frac{V_{max}}{2^n - 1} \tag{1}$$

where n is the number of bits and $q = 2^n$ is the number of levels.

Signal-to-Quantization Ratio

The ith sample after quantization my be expressed as

$$m_{\delta_q}(t) = m(t_i) + \epsilon(t_i) \tag{2}$$

The signal-to-quantization ratio is defined as

$$(SNR)_Q = \frac{\overline{m^2(t)}}{\overline{\epsilon^2(t)}} \tag{3}$$

and assuming the quantization error is uniform

$$\frac{-1}{2}\Delta \leq \epsilon(t_i) \leq \frac{1}{2}\Delta \tag{4}$$

therefore, and assuming $m(t)$ is uniform,

$$(SNR)_Q = 12\frac{\overline{m^2(t)}}{\Delta^2} = 2^{2n} \tag{5}$$

Word-Error Probability

$$P_w = 1 - (1 - P_b)^n \tag{6}$$

where P_b is the bit-error probability and P_w is the word-error probability. The effect of word error is in the range of

$$\frac{-1}{2} q\Delta \leq \epsilon_w \leq \frac{1}{2} q\Delta \tag{7}$$

Assuming P_w is negligible

$$(SNR)_D = 2^{2n} \tag{8}$$

which in dB is

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which in dB is

$$10 \log_{10}(SNR)_D = 6.02n \tag{9}$$

Dithering

Dithering a method to statistically reduce quantization errors and harmonic distortion in analog-to-digital converters. This is achieved by adding a signal uncorrelated with the input before sampling. This signal may be a broadband noise in the signal bandwidth or a narrowband noise close to the Nyquist frequency.

DAC Types

- R-2R resistor ladder network.
- Binary weighted.
- Oversampling DACs.

R-2R ladder network

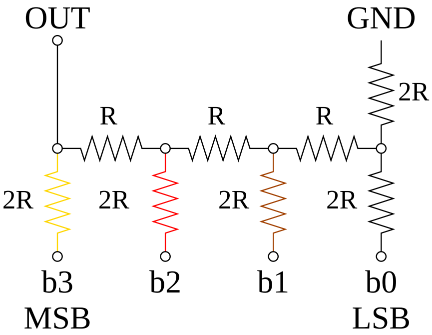

Figure: 4-bit R2R resistor ladder

Binary Weighted

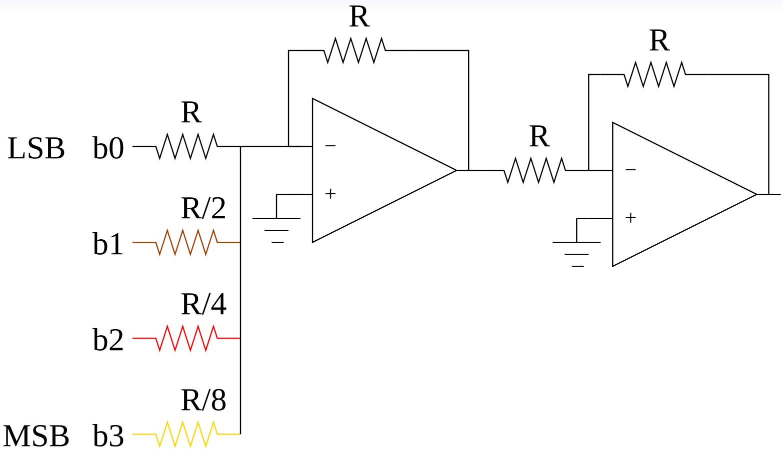

Figure: 4-bit binary weighted converter

Oversampling DAC

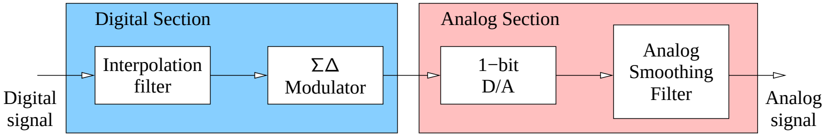

Figure: Elements of an oversampling DAC

ADC Types

- Successive approximation.
- Dual slope, integrating converters.
- Sigma-Delta converters.
- Flash converters.

Successive Approximation

1. Works by comparing a the signal to different quantization levels.
2. Low cost and moderate complexity.
3. Accuracies ranging 8-16 bits.
4. Fast enough for audio signals.

Dual Slope

1. Works by ramping up a signal linearly. A counter is used to to measure the time required to reach the input signal.
2. Accuracies up to 22-bits.
3. Slow conversion time.
4. High frequency noise rejection.

Sigma-Delta ADC

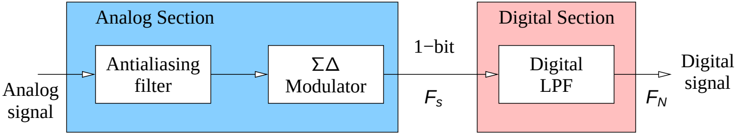

Figure: Elements of an oversampling ADC

Flash ADCs

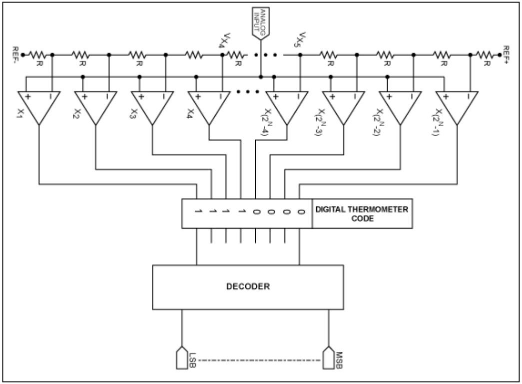

Figure: Flash ADC

Trade-offs

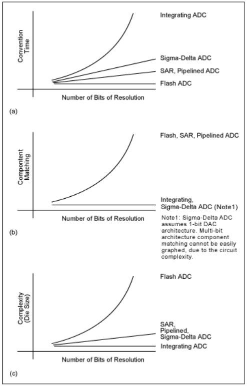

Figure: Trade-offs

Overview

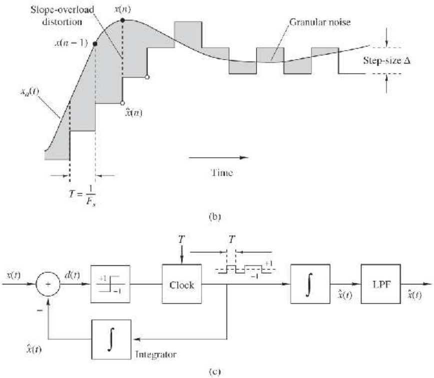

Figure: ©J.G. Proakis and D.G. Moanolakis, *Digital Signal Processing*, 4th Edition, Prentice Hall, 2007