Examination of Integrated A/D and D/A Converters

14.00-19.00, Friday, Dec 14, 2007

I. Basic questions about A/D converters

a) Assuming the quantization error ε_Q is distributed from $-\Delta/2$ to $+\Delta/2$ (where Δ is the quantization step) with uniform probability $p(\varepsilon_Q)$, write the expressions of the error power P_Q and the *rms* error voltage V_Q as functions of Δ (remember that P_Q is given by the integration

$$P_Q = \int_{-\infty}^{\infty} \varepsilon_Q^2 \cdot p\left(\varepsilon_Q\right) d\varepsilon_Q$$

b) Express the *rms* voltage of a full-scale sinusoidal input signal in terms of the quantization step Δ for an n-bit A/D converter.

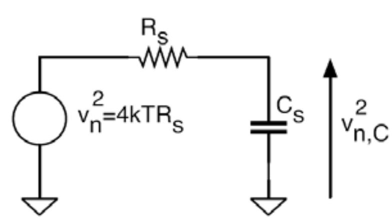
c) Write the expression of the *rms* signal-to-quantization noise ratio (SNR) as a function of n, when the input signal is a full-scale sinusoid.

d) Does bandwidth over which the quantization noise is spread depend on the sampling frequency f_s? If so, express their relation. Furthermore, what conditions should be satisfied in order to assume that the quantization noise has a white spectral density?

e) What is the Nyquist bandwidth of an A/D converter, and what is its relation with the sampling frequency f_s? What happens when the bandwidth of the input signal is larger than the Nyquist bandwidth?

f) Another fundamental limit in the SNR of A/D converters is set by thermal noise. For the circuit below, show that the thermal noise power P_C across capacitance C_S is independent of R_S, and derive its expression using the integration

$$P_C = \int_0^{\infty} v_{n,C}^2\left(f\right) df$$



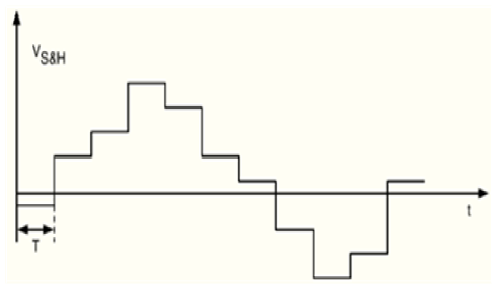
g) Yet another limit in the SNR of A/D converters is set by "jitter". What do we mean by that? Explain qualitatively why the impact of jitter grows with the frequency of the input signal.

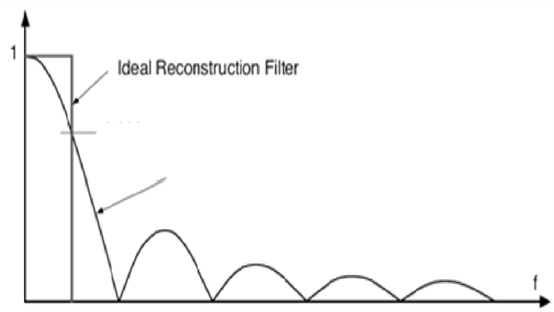
II. Basic questions about D/A converters

a) The signal waveform after the sample-and-hold (S&H) of a D/A converter is shown on the left, and the amplitude response of the ideal and the real S&H are shown on the right. Remembering that the transfer function of the real S&H is

$$H_{S\&H}(s) = \frac{1 - e^{-sT}}{s\tau}$$

where $T=1/f_s$ (f_s = sampling frequency) and τ is a suitable gain factor. Derive an expression for the amplitude of $H_{S\&H}(j\omega)$, and find the frequencies at which $H_{S\&H}(j\omega)$ is null. How much has $H_{S\&H}(j\omega)$ dropped at the Nyquist frequency, compared to its low-frequency value?





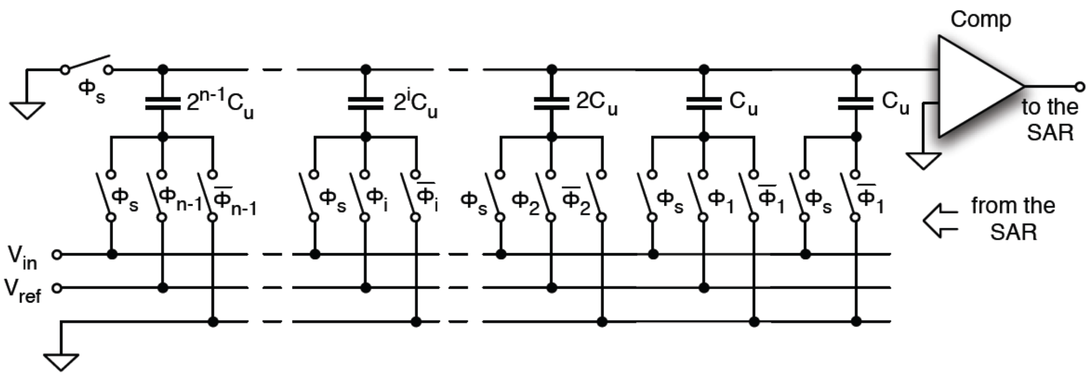
b) Why is a reconstruction filter usually needed after a D/A converter? In what way does it help to have a large ratio of f_s to f_B, where f_B is the signal bandwidth?

III. Basic questions about ΣΔ converters

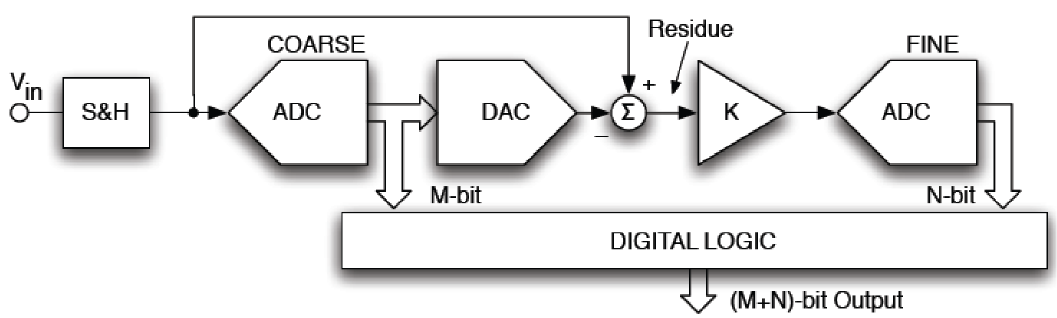
a) What are the key ideas behind ΣΔ converters? What are the main advantages of ΣΔ converters over Nyquist converters?
b) Why is it difficult to replace a full-flash converter with a ΣΔ converter?
c) What particular implementation of a ΣΔ converter is intrinsically linear (excluding second-order effects)?
d) What is the purpose of the "dynamic element matching" technique?

VI. Specific questions about converters

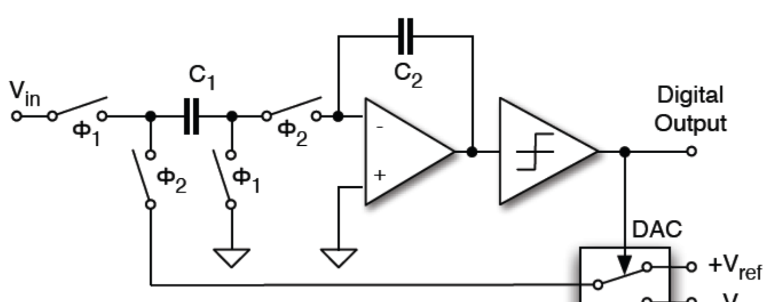
a) What kind of converter is the one below? Explain how it works, and how sampling frequency and clock frequency are related



b) What kind of converter is the one below? Explain how it works, how sampling frequency and clock frequency are related, and why it is often an attractive alternative to a flash converter.

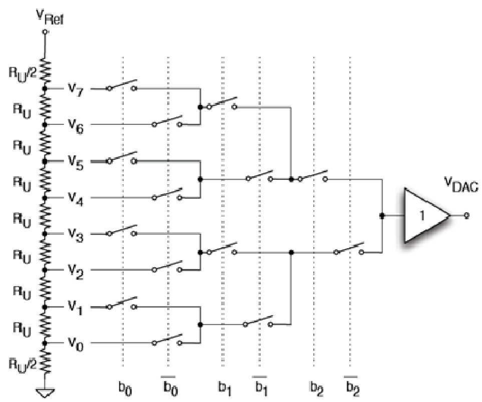


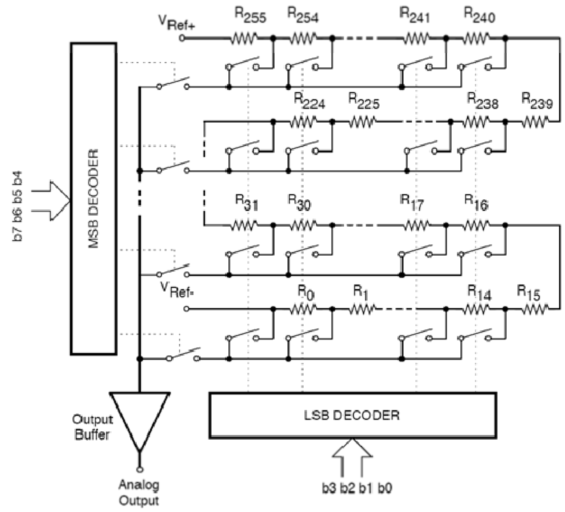
c) What kind of converter is the one below? Explain the operations of the various blocks.



(a)

d) We see below the most straightforward implementation of a resistive-ladder D/A converter (left). What is its main drawback, and how is it alleviated by the alternative implementation to the right?





e) Why is it a not a good idea to implement the current sources in a current-based D/A converter as simple current mirrors? Are there better alternatives?

f) What might be the use of the circuit below? Where is it used?