

S21EC5.201 Signal Processing

Initial Project Report

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Assigned Paper:

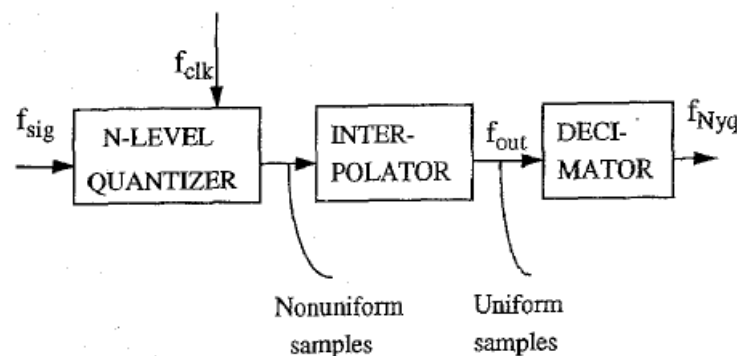
A Level-Crossing Sampling Scheme for A/D Conversion

<https://ieeexplore.ieee.org/document/488288>

Project Summary:

The paper discusses about a sampling scheme based on level-crossings. The samples are recorded at nonuniform time intervals (In contrast with uniform sampling), when the signal crosses any of the known quantization levels (or level-crossings). This can be thought of as an intermediate sampling scheme between the Nyquist rate sampling and zero-crossing sampling. The rate of sampling will largely depend on the input signal.

Using the multiple level-crossing sampling scheme, a model of an Analog-to-Digital Converter is presented, a figure of which is given below.



Steps Involved in A/D conversion:

1. Signal acquisition and quantizer stage –

The input signal is fed into the N-level quantizer at an input frequency f_{sig} . To measure the instance of level-crossings, we have a clock frequency of $f_{clk} = 1/T$. The quantization levels are known with an uncertainty of δ_a , where $L = -\log_2(2\delta_a)$ is defined as the number of bits of amplitude resolution. The resolution in time

is $R = 1/(f_s T)$. Each time the signal crosses any of the quantization levels, the time instance is recorded with resolution R , along with the quantization level.

Here, the accuracy of this process depends on the number of quantization levels, the amplitude resolution, and the time resolution. The number of quantization levels and R is dependent are variables associated with the level-crossing sampling scheme.

2. Interpolator Stage –

The acquired nonuniform samples are fed into an interpolator and uniform samples are generated at a sampling frequency f_{out} . The extent and accuracy of interpolation depends on the type of interpolation employed and the interpolation order.

3. Decimator stage –

The uniform samples are further decimated to increase the resolution of the A/D converter. The decimator employed has a decimation factor $DF = f_{out}/f_{Nyq}$. The extent of effect of decimation on the resolution of the A/D converter depends on the noise content present in the signal, and the ratio $FR = f_{SB}/f_s$, where f_{SB} is the signal bandwidth. The A/D converted signal is outputted at the Nyquist frequency of the input signal.

There are various trade-offs on the SNR produced by the A/D converter (which ultimately tells about the accuracy of the A/D converter) dependent on the number of quantization levels, R , L , interpolation order and DF .

Design procedure –

Depending on our application, we must define a minimum quantization level resolution L which ensures our quantization error is at a minimum for our required SNR. We then find our maximum resolution ratio R at which SNR cannot noticeably improve any further (our saturation point, which can improve with a better interpolation method), and choose a combination of R (not exceeding the threshold) and DF that satisfies the saturation point. We finally then decide on the minimum number of quantization levels needed for our saturation point R .

Project Objective / Timeline:

1. We wish to design and discuss the mentioned level-crossing sampling scheme and A/D converter, and the trade-offs associated with number of quantization levels, R , L , interpolation order and DF (the variables associated with the A/D converter and sampling scheme).
2. Implement the multiple level-crossing sampling scheme and A/D converter in MATLAB.

3. Compare and contrast the trade-offs of the variables associated with the A/D converter and sampling scheme with relevant examples and plots.
4. Determine an adequate set of values of R , number of quantization levels, DF , interpolation order etc. for these examples with the design procedure mentioned in the assigned paper.

References:

1. N. Sayiner, H. V. Sorensen, and T. R. Viswanathan, "A level-crossing sampling scheme for A/D conversion," *IEEE Trans. Circuits Syst. II: Analog Digit. Signal Process.*, vol. 43, pp. 335–339, Apr. 1996.
2. N. Sayiner, H. V. Sorensen and T. R. Viswanathan, "A new signal acquisition technique", *Proc. 35th Midwest Symp. Circuits Syst.*, pp. 1140-1142, 1992-Aug
3. N. Sayiner, H. V. Sorensen and T. R. Viswanathan, "A nonuniform sampling technique for A/D conversion", *Proc. 1993 Int. Symp. Circuits Syst.*, pp. 1220-1223, 1993-May.
4. Chapter 11 – Multirate Digital Signal Processing, *Digital Signal Processing*, 4th Edition, by John Proakis and Dimitris Manolakis.