

Effects of finite word length representation of the filter coefficients

Lab, SDP

Objective

Students should observe the effects of having fixed point coefficients in a digital filter, and be able to mitigate the effects.

Theoretical notions

Exercises

1. Convert the following binary number to the decimal value:
11011.0101
2. Convert in binary fixed point format (signed, 6 integer bits, 6 fractionary bits - 1S6I6F the following numbers:
273.21875
3. Convert in binary fixed point format (signed, 6 integer bits, 6 fractionary bits - 1S6I6F the following negative numbers. Negative numbers shall be represented in sign-value, 1's complement (C1) and 2's complement (C2) formats.
 - a. -273
 - b. -273.21875
4. Quantize the samples $x_1 = 0.42625$ and $x_2 = -0.4333$ the fixed point format 1S0I4F via:
 - a. Truncation
 - b. Rounding
 - c. Truncation in absolute value

The negative values shall be represented in C2 format.

5. Use Matlab's `fdatool` to design a low-pass IIR filter, Butterworth type, order 4, with cutoff frequency of 4kHz for a sampling frequency of 44.1kHz. Export the coefficients of the direct form II implementation to the Matlab Workspace as **b** and **a**.
6. In Matlab's `fdatool`, set the filter arithmetic to "fixed-point arithmetic" and modify the following:
 - a. Set the format to fixed point 1S2I7F. How does the filter's transfer function change?
 - b. Increase the number of bits in the fractionary part. How does the filter's transfer function change? For what number of bits do you consider the errors to be negligible?
 - c. Export the coefficients of the direct form II implementation to Matlab's Workspace as **b1** and **a1**.
7. Repeat the preceding exercise with the filter implemented in series form ("Second-Order-Sections"). Which implementation has smallest errors? Export the coefficients to Matlab's Workspace as **b2** and **a2**.
8. Load the `mtlb` audio signal from Matlab. Use `filter()` to filter the signal with the original filter (**b** and **a**) and with the fixed point coefficients (**b1** and **a1**).
 - a. Plot the difference between the two filtered signals.
 - b. Plot the histogram of the difference signal. What is it's shape? What is the average value of the errors?

Final questions

1. TBD