Exercise 2. CIC Filtered data. Due Monday Feb 13, 2017, 20:00. Weight 2 points.

Assume that a voltage is measured and digitized by an ADC. This ADC can measure at a rate of 1.024 MHz and has 18 bits, so the full scale runs from -2^{17} to $+2^{17}-1$.The ADC has a noise floor of 2 bits; the values that are measured contain Gaussian-distributed noise with a mean of 0 and a RMS of 3.
The user is interested in accurate data at low frequencies, frequencies below 500 Hz. Therefore, with this ADC the data is oversampled and downsampled with a factor of 1024, to gain 5 bits accuracy. The downsampling and averaging is done with a 4-fold CIC filter, downsampling factor M=1024 (so the input rate is 1024 kHz and the output rate 1 kHz). (If you read in the literature, CIC filters can have delays of DM samples with D an integer and M the downsampling factor. We use the conventional D=1: from the sums, the previous sum DM samples earlier is subtracted).

The file on the web page (www.nikhef.nl/~henkjan, click on Computational Methods, click on data.txt behind exercise 1) contains 2048000 ADC samples. It contains the signal and noise. The signal is given by s(t) = 2.7sin(17t) and is smaller than the noise. However, with the 4-fold CIC filter it can be reproduced quite accurately.

Make a plot in which for every ms (2000 values in time) the datasample, the signal, and the CIC filter output is shown. To see the quality improvement, also calculate the RMS of the datasample minus the signal and of the CIC filter output minus the signal at (t-0.002) seconds (i.e. take the CIC filter delay into account). (The RMS is given by

$$RMS=\sqrt{\frac{1}{n}\sum_{i=0}^{n-1}(d_i-s_i)^2}$$

$$RMS=\sqrt{\frac{1}{n-2}\sum_{i=2}^{n-1}(CIC_i-s_{i-2})^2}$$

with s_i the signal at millisecond i, d_i the datasample, and CIC_i the normalized CIC filter output).

Mail the plot, your source code, and the 2 RMS values to henkjan@nikhef.nl before the deadline.