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New DAQ Decimation Filters

LIGO-T1600059-v2
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The DAQ system uses IIR low-pass filters for data decimation when the specified frame storage rate for a channel is smaller than the rate of the RCG model that contains that channel. The filters used through O1 are described in LIGO-T1400719. An undesirable feature of these low-pass filters is that the cut-off frequency is at approximately 75% of the down-sampled Nyquist frequency (even closer to 50% for the higher decimation factors), removing useful bandwidth from the archived data. This note defines new filters that have cut-off frequencies at 90% of the down-sampled Nyquist frequency. The filter order (6^{th}) and stop-band attenuation (-60 dB) is the same as before. The matlab design string for the new filters is:

ellip(6, 0.3, 60, 0.9 * (1/dfactor))

where 'dfactor' is the decimation factor (power of 2). This is a 6^{th}-order elliptic filter, with a pass-band ripple of 0.3 dB and stop-band of -60 dB.

Filter coefficients

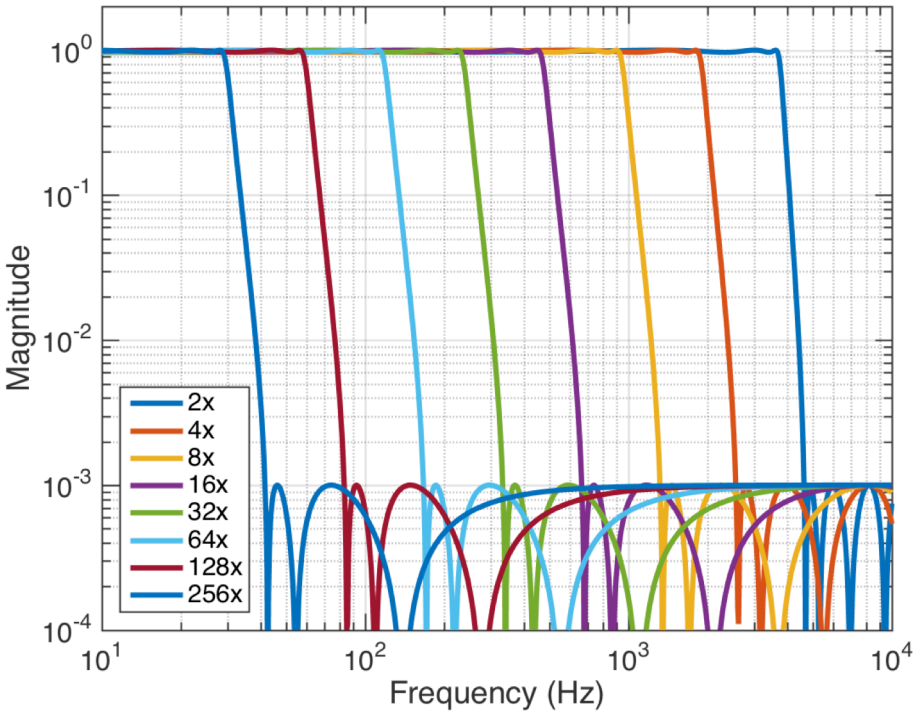
Filters are defined for power-of-2 decimations, from 2x to 256x. Each filter contains 3 second-order-sections (SOS). The filter coefficients are given below: the first is a gain factor, followed by one row for each of the SOS.

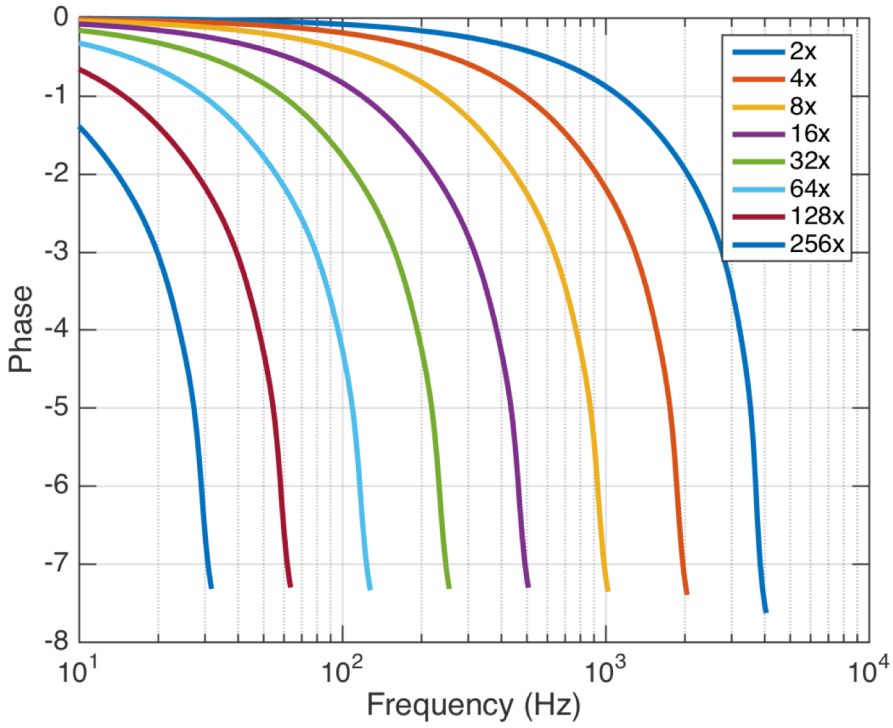
```
// Decimation filter coefficient definitions.

static double dCoeff2x[13] = {0.02717257186578,
-0.88409445909120, 0.29163278222038, 1.77827289469673, 1.00000000000000,
-0.50494842547525, 0.60956783650356, 0.89689627764092, 1.00000000000000,
-0.25856603406288, 0.88597422654601, 0.46331872573378, 1.00000000000000}

static double dCoeff4x[13] = {0.00426219526013,
-1.46640482430571, 0.57261418353576, 1.04291599189547, 1.00000000000000,
-1.43602772908265, 0.74619627655392, -0.68459245534721, 1.00000000000000,
-1.44571894955428, 0.92263940595263, -1.07907796826425, 1.00000000000000}


static double dCoeff8x[13] = {0.00162185538923,
-1.73342532779703, 0.76204897871017, -0.29232406818199, 1.00000000000000,
-1.77657563380963, 0.85961875056357, -1.58806235217539, 1.00000000000000,
-1.83213081484618, 0.95786576675891, -1.73803961693533, 1.00000000000000}

static double dCoeff16x[13] = {0.00112590539483,
-1.86616831686611, 0.87370486321597, -1.38030026660129, 1.00000000000000,
-1.90508101474565, 0.92661598590013, -1.89009233048750, 1.00000000000000,
-1.94631370100442, 0.97835549656052, -1.93218554040168, 1.00000000000000}

static double dCoeff32x[13] = {0.00102945292275,
-1.93288074072411, 0.93482166869425, -1.82536173520820, 1.00000000000000,
-1.95705391699530, 0.96253965472870, -1.97205371579193, 1.00000000000000,
-1.98100244642901, 0.98907393282162, -1.98289480583941, 1.00000000000000}
```

```
static double dCoeff64x[13] = {0.00101894798776,
-1.96638168022541, 0.96687465485337, -1.95490597403406, 1.00000000000000,
-1.97969775930388, 0.98108225201938, -1.99298346945427, 1.00000000000000,
-1.99249184543014, 0.99451634521150, -1.99571412470436, 1.00000000000000}

static double dCoeff128x[13] = {0.00102359688929,
-1.98317523053482, 0.98329948472592, -1.98863312775467, 1.00000000000000,
-1.99014707880010, 0.99049485279657, -1.99824398492604, 1.00000000000000,
-1.99674681025230, 0.99725369912944, -1.99892793100025, 1.00000000000000}

static double dCoeff256x[13] = {0.00102849104272,
-1.99158359864769, 0.99161479126471, -1.99715238605202, 1.00000000000000,
-1.99514878857652, 0.99523593955780, -1.99956087842252, 1.00000000000000,
-1.99849900371282, 0.99862581732555, -1.99973194521355, 1.00000000000000}
```

Transfer functions

The transfer functions for these filters are shown below, for a sampling frequency of 16384 Hz. The phase is plotted only up to the down-sampled Nyquist frequency. There is no compensation for the non-linear phase shift introduced by the filter.


Magnitude
Frequency (Hz)
2x
4x
8x
16x
32x
64x
128x
256x


Phase
Frequency (Hz)
2x
4x
8x
16x
32x
64x
128x
256x