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A Note on the DAQ Decimation Filters

LIGO-T1400719-v1
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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 currently in use apparently harken back to initial LIGO, but their provenance is not clear, and any design criteria seem to have been lost to history. The purpose of this note is to document the filters being used.

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] =
    {0.014605318489015,
     -1.00613305346332,    0.31290490560439,    -0.00000330106714,    0.99667220785946,
     -0.85833656728801,    0.58019077541120,    0.30560272900767,    0.98043281669062,
     -0.77769970124012,    0.87790692599199,    1.65459644813269,    1.00000000000000};
static double dCoeff4x[13] =
    {0.0032897561126272,
     -1.52626060254343,    0.60240176412244,    -1.41321371411946,    0.99858678588255,
     -1.57309308067347,    0.75430004092087,    -1.11957678237524,    0.98454170534006,
     -1.65602262774366,    0.92929745639579,    0.26582650057056,    0.99777026734589};
static double dCoeff8x[13] =
    {0.0019451746049824,
     -1.75819687682033,    0.77900344926987,    -1.84669761259482,    0.99885145868275,
     -1.81776674036645,    0.86625937590562,    -1.73730291821706,    0.97396693941237,
     -1.89162859406079,    0.96263319997793,    -0.81263245399030,    0.83542699550059};
static double dCoeff16x[13] =
    {0.0010292496296221,
     -1.88217952734904,    0.88726069063363,    -1.96157059223343,    1.00000000000000,
     -1.92138912262668,    0.93301587832254,    -1.93613544029360,    1.00000000000000,
     -1.96312311206509,    0.97976907054276,    -1.61069820496735,    1.00000000000000};
static double dCoeff32x[13] =
    {0.00099066651652901,
     -1.94077236718909,    0.94207456685786,    -1.99036946487329,    1.00000000000000,
     -1.96299410148309,    0.96594271100631,    -1.98391795425616,    1.00000000000000,
     -1.98564991068275,    0.98982555984543,    -1.89550394774336,    1.00000000000000};
static double dCoeff64x[13] =
    {9.117708813402705e-05,
     -1.9884411147668981,    0.9887377424723078,    -1.9981756949239626,    1.00000000000000,
     -1.9958880030565560,    0.9964854389877406,    -1.9957606929166283,    1.00000000000000,
     -0.9920419803627476,    0.00000000000000,    1.00000000000000,    0.00000000000000};
static double dCoeff128x[13] =
    {4.580254440937838e-05,
     -1.9942785038368447,    0.9943528687022676,    -1.9995438020236211,    0.99999999999999,
     -1.9980915472248755,    0.9982410430658426,    -1.9989394099812350,    1.00000000000000,
     -0.9960132079520891,    0.00000000000000,    1.00000000000000,    0.00000000000000};
static double dCoeff256x[13] =
    {2.296084727953743e-05,
     -1.9971538121386385,    0.9971724295485971,    -1.9998859428966878,    1.00000000000000,
     -1.9990827274780281,    0.9991201182251324,    -1.9997348047494339,    0.99999999999999,
     -0.9980046339426777,    0.00000000000000,    1.00000000000000,    0.00000000000000};
```

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 downsampled Nyquist frequency. Note that there is no compensation for the non-linear phase shift introduced by the filter. Another undesirable feature is that the cut-off frequency of each low-pass filter is at approximately 75% of the downsampled Nyquist frequency (even closer to 50% for the higher decimation factors), rather than something like 90%.

