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## A Note on the RCG Decimation Filters

LIGO-T1500075-v1  
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The real-time code generator (RCG) uses IIR low-pass filters for data decimation to go from the sample rate of the input-output processor (iop) to the sample rate used by an individual RCG model. The iop rate is 65536 Hz, both for input (from ADC) and output (to DAC). There are 4 options for the RCG model rate:  $32768\text{ s}^{-1}$ ,  $16384\text{ s}^{-1}$ ,  $4096\text{ s}^{-1}$ ,  $2048\text{ s}^{-1}$ . 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.
case '32k'
    /* Coeffs for the 2x downsampling (32K system) filter */
    static double __attribute__((unused)) feCoeff2x[9] =
        {0.053628649721183,
         0.2568759660371100, -0.3225906481359000, 1.2568801238621801, 1.6774135096891700,
         -0.2061764045745400, -1.0941543149527400, 2.0846376586498803, 2.1966597482716801};

case '16k'
    /* Coeffs for the 4x downsampling (16K system) filter */
    static double __attribute__((unused)) feCoeff4x[9] =
        {0.014805052402446,
         0.7166258547451800, -0.0683289874517300, 0.3031629575762000, 0.5171469569032900,
         0.6838596423885499, -0.2534855521841101, 1.6838609161411500, 1.7447155374502499};

case '4k'
    /* // New Brian Lantz 4k decimation filter
    static double __attribute__((unused)) feCoeff16x[9] =
        {0.010203728365,
         0.8052941009065100, -0.0241751519071000, 0.3920490703701900, 0.5612099784288400,
         0.8339678987936501, -0.0376022631287799, -0.0131581721533700, 0.1145865116421301};

case '2k'
    /* Coeffs for the 32x downsampling filter (2K system) */
    /* Original Rana coeffs from 40m lab elog */
    static double __attribute__((unused)) feCoeff32x[9] =
        {0.0001104130574447,
         0.9701834961388200, -0.0010837026165800, -0.0200761119821899, 0.0085463156103800,
         0.9871502388637901, -0.0039246182095299, 3.9871502388637898, 3.9960753817904697};
```

## Transfer functions

The transfer functions for these filters are shown below (32k option omitted), for a sampling frequency of 65536 Hz. The phase is plotted only up 1000 Hz because one is usually just interested in the phase lag around the servo unity gain frequency. Note that a digital servo will experience 2 of these phase lags, one at the input and one at the output. For example, the IO phase delay for a 16k servo, at 200 Hz, is 8 degrees.

