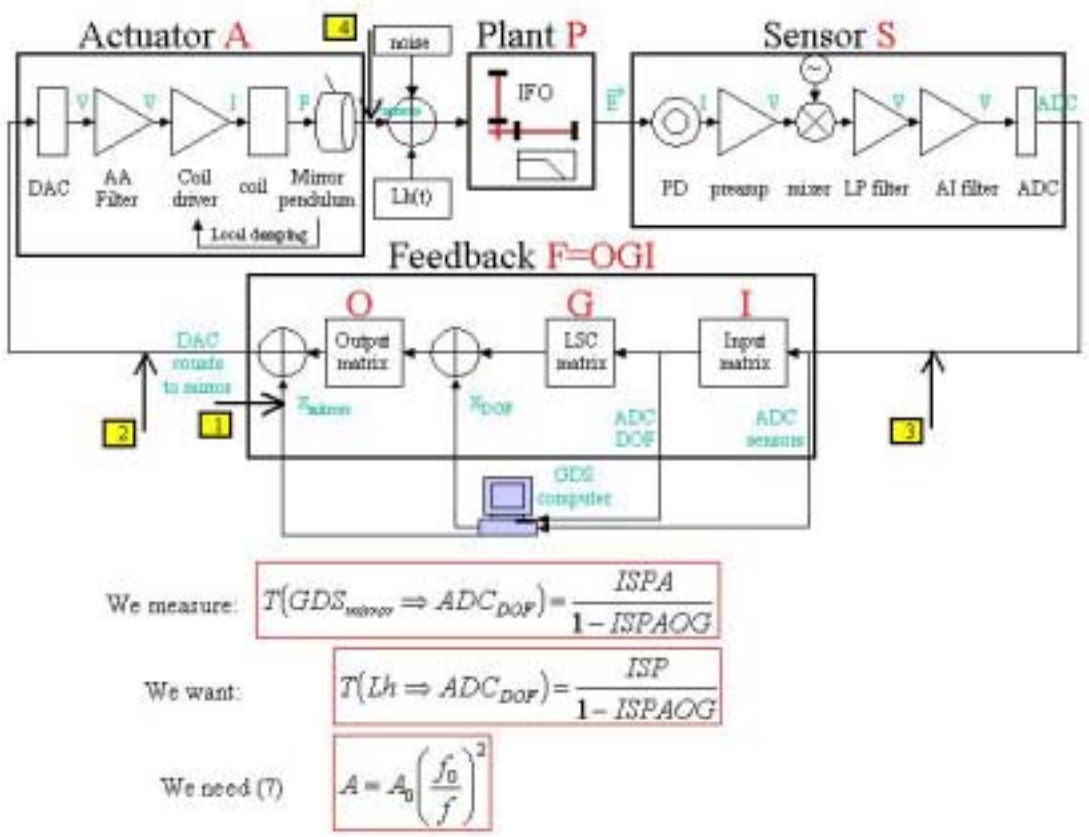
Calibration and MC simulation

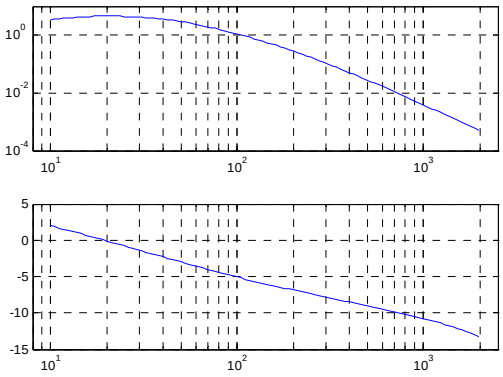
AJW, 4/22/01

Here's an overview of the LIGO calibration system:



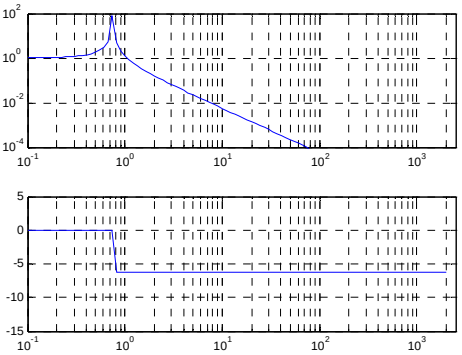
- The actuator is the OSEM. It's pretty high bandwidth, except for the suspension pendulum. Thus, it is assumed that A(f) is dominated by the pendulum double-pole, $A(f) = -f_0^2 / (f^2 - f_0^2 - i f_0^2 \phi_0^2)$, with $f_0 = 0.744$ Hz, and $\phi_0 \sim$ 1e-5.
- The sensor is presumably a constant, independent of f.
- The plant is presumably dominated by the cavity pole
  $P(f) = -f_p^2 / (f^2 - f_p^2 - i f_p^2 \phi_p^2)$, with $f_p = 91$ Hz for 4K, 182 Hz for 2K.
- The Input matrix is a constant matrix converting from 4 sensors (eg, ASY_Q) to degrees of freedom L_+, L_-, l_+, l_- . (Matt's code is more complicated during acquisition). It is set using measurements made as part of calibration.
- The Output matrix converts from DOFs to mirrors: [1 1 ; -1 1]/2.
- The LSC matrix is a bunch of complicated filters, whose net effect is obtained from transfer function measurements.
- The calibration procedure measures the transfer function from 1 to 3 (closed loop) or 2 to 3 (open-loop) from ~10 Hz to ~3000 Hz. The result from E2 (H2K) is given in G010057 (E2 Calibration, Landry et al) page 7.

- The fit to the transfer function detail is given in G010057 p 10 and is shown here:

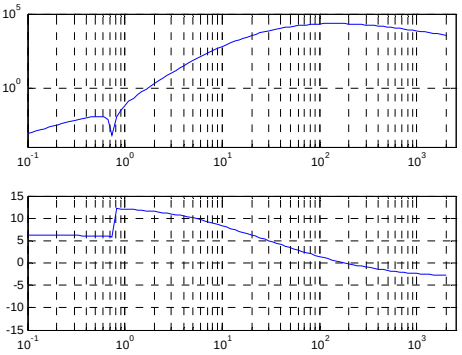


Fit to data from ETM_y transfer function from E2. Top: magnitude; Bot: phase.

- The overal magnitude of this transfer function is in more-or-less arbitrary units, and it can be normalized correctly using the information in G010057 p 13; to be done.
- We need the transfer function between 4 and 3 (the GW path) so we need to divide by the actuator (pendulum) transfer function A(f).

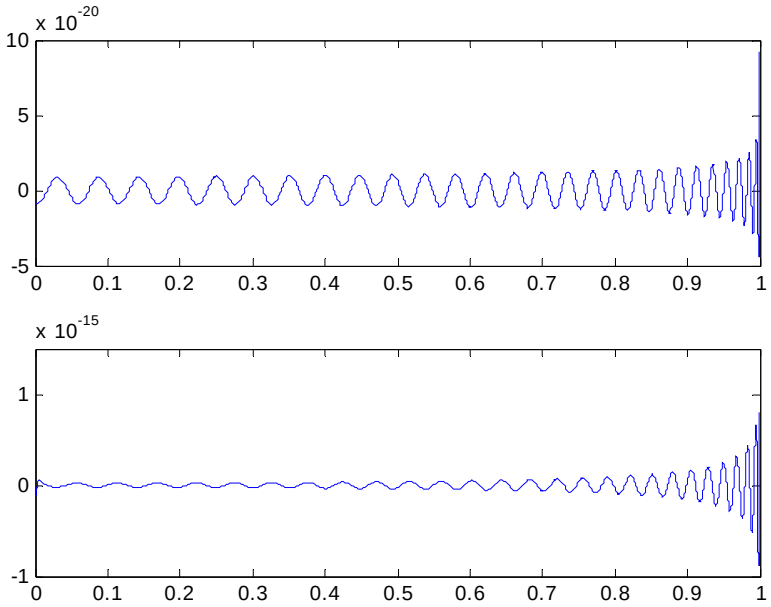


Pendulum transfer function



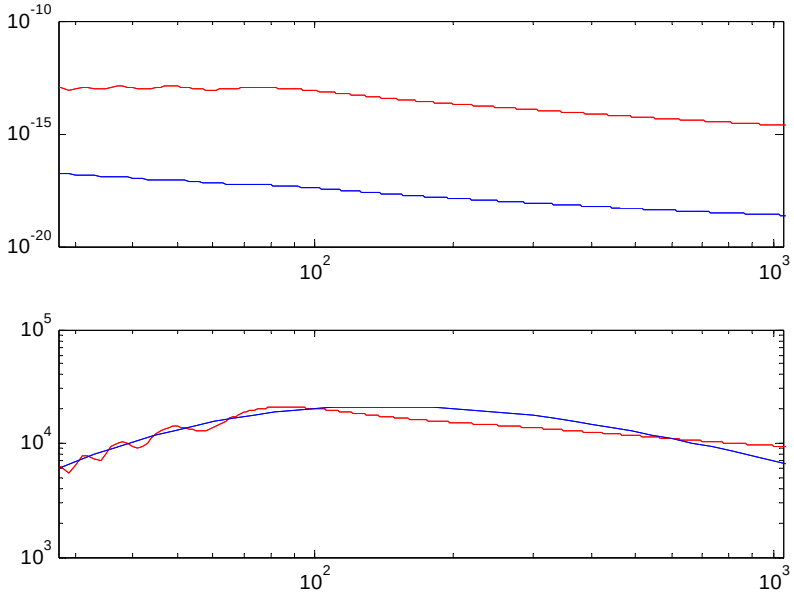
Transfer function from mirror position to ADC counts. Only the part from f > 10 is meaningful, since it is not measured below that. And, the overall scale needs calibrating.

- So if we generate a chirp h(t), we must filter it through the above transfer function before we add it to noise (in ADC counts) from real engineering data. This is illustrated below:



Top: A chirp. Bottom: a chirp, filtered through the LIGO E2 transfer function. Again, overall scale must be calibrated.

- We can check this by FFTing both signals, taking their ratio, and comparing it with the parameterized transfer function of LIGO, as shown below.



Top: FFT of original chirp (blue) and filtered chirp (red). Bottom: filtered/original (red) and LIGO transfer function (blue).