Computation exercise 4(a): Dynamic Error Budgeting

Mechatronic systems
376.050
2016W

Important: Answers must be a hard copy and submitted to the office in CA0421 by January 11, 2017 at 4pm. The work must be original. For questions about this exercise, please contact Mr. Thier (thier@acin.tuwien.ac.at).

Fig. 1 shows a lumped mass model of a positioning system actuated by a flexure-guided Lorentz actuator on a vibrating floor. The position x_m of the moving mass m is measured by a position sensor to regulate by feedback control $C(s)$ rejecting the floor vibrations. Fig. 2 shows the control block diagram, where $P_a(s)$ and $P_t(s)$ are the plant with position reference r, position error e, sensor noise n, floor motion in velocity $v_f = \dot{x}_f$ and actuation force F. The mechanical parameters are given in Table 1 together with the spectral density of n and $\dot{x}_f$. By assuming that these spectral densities uniformly exit only between 1 Hz and 1 kHz, answer the questions with the following feedback controller

$$C(s) = 3m{\omega_c}^2 \frac{(s + 0.1\omega_c)(s + \omega_c/3)}{s(s + 3\omega_c)}.$$

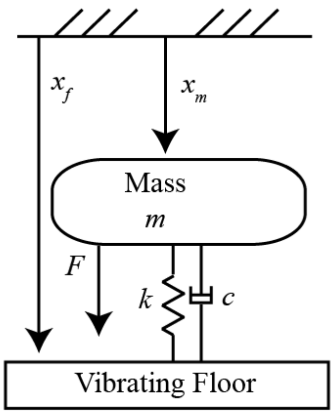

Fig. 1: Lumped mass model.

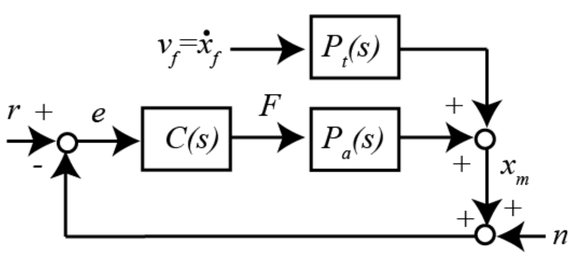

Fig. 2: Block diagram

Table 1: Parameters

Param.	Description
m	2 g
c	0.02 N/(m/s)
k	20 N/m
n	1 nm/$\sqrt{Hz}$
v_f	2 (μm/s)/$\sqrt{Hz}$
ω_c	2π×100 rad/s

i. Derive a transfer function from n to x_m and a transfer function from v_f to x_m, respectively. [10%]

ii. Draw Bode plots of the transfer functions in (i). [5 %]

iii. Calculate the power spectral density of x_m by considering the sensor noise n, and plot it as a function of frequency. [15 %]

iv. Calculate the positioning resolution of the system (i.e. standard deviation of x_m) resulting from the sensor noise n. [15 %]

v. Calculate the positioning resolution resulting from the floor vibrations v_f. [20 %]

vi. Calculate the overall positioning resolution by considering both the sensor noise and the floor vibrations. [15 %]

vii. Simulate the overall positioning resolution for a case that the control bandwidth (ω_c) is decreased by half. Using the results, discuss the influence of the sensor noise and the floor vibrations on the achievable positioning resolution individually. [20 %]