Question 1

Complete

Mark 8.00 out of 8.00

A car suspension model is shown in figure below. The quantities $x_1(t)$ and $x_2(t)$ are vertical displacements in car body and car wheel respectively due to displacement $d(t)$ induced by an uneven road. A comfortable ride is one where a passenger would experience less movement due to road roughness. A quantity of interest that roughly captures the level of comfort in a ride and road holding ability is (x_1(t)-x_2(t)\). An actuator is placed between masses M1 and M2 that exerts equal force $u(t)$ at M1 and M2 as shown. Take M_1 =240, M_2 =40, k =10000, f_v =800 and k_t =100000.

i) Compute the transfer function $G_d(s)$ from road disturbance $d(t)$ to \ $x_1(t) - x_2(t)$. (Assume u(t)=0)

$$G_d(s) = L_d \frac{s^2 + b_1 s + b_0}{s^4 + a_3 s^3 + a_2 s^2 + a_1 s + a_0}$$

ii) Compute the transfer function $G_u(s)$ from input $u(t)$ to \ $x_1(t) - x_2(t)$. (Assume d(t)=0)

$$G_u(s) = L_u \frac{s^2 + m_1 s + m_0}{s^4 + l_3 s^3 + l_2 s^2 + l_1 s + l_0}$$

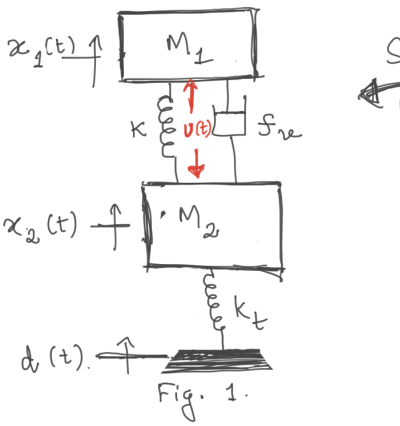
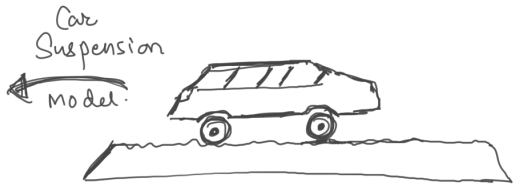


Fig. 1.



M_1 → Mass of car body

M_2 → Mass of wheel.

k_t → Spring constant of tyres.

$d(t)$ → displacement due to Roughness in road

$u(t)$ → Control force applied to Masses

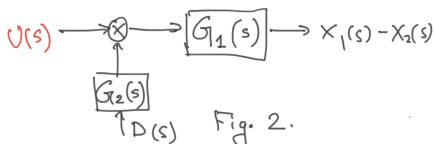


Fig. 2.

$G_d(s) =$ -2500 . (s^2+ 0 s+ 0)/(s^4+ 23.333 s^3+ 2791.6 s^2+ 8333.3 s+ 10416)

One possible correct answer is: -2500, 0, 0, 23.333333333333, 2791.6666666667, 8333.3333333333, 104166.66666667

$G_u(s) =$ 0.0291 . (s^2+ 0 s+ 357.14)/(s^4+ 23.333 s^3+ 2791.6 s^2+ 8333.3 s+ 10416)

One possible correct answer is: 0.029166666666667, 0, 357.14285714286, 23.333333333333, 2791.6666666667, 8333.3333333333, 104166.66666667

Now, the overall open loop system can be represented by the block diagram shown in Fig.2. Compute $G_1(s) =$ 0.0291 . (s^2+ 0 s+ 357.14)/(s^4+ 23.333 s^3+ 2791.6 s^2+ 8333.3 s+ 104166) and

One possible correct answer is: 0.029166666666667, 0, 357.14285714286, 23.333333333333, 2791.6666666667, 8333.3333333333, 104166.66666667

$G_2(s) =$ -85714 s^2/(s^2+ 357.14).

One possible correct answer is: -85714.285714286, 357.14285714286

Your answer is correct.

Comment:

Question 2

Complete

Mark 12.00 out of 12.00

Now, that we have obtained a block diagram for suspension system as shown in Fig.2, we want that irrespective of $d(t)$, the output $y = x_1 - x_2$ remains as low as possible.

1. Assuming no compensation i.e., input force $u(t) = 0$, simulate the system obtained in block diagram of Fig. 2 in previous question for "*step*" disturbance. Choose the magnitude of step disturbance to be 0.1. Describe and explain your observation.
2. Assuming a reference signal of $R(s) = 0$, we want to choose the control input by setting up a feedbacl loop using $U(s) = G_{compensator}(s)(R(s) - Y(s))$. Design a suitable (choose from P/PI/PD/PID/Lag/Lead/Lag-lead/Notch filter) compensator that leads to a comfortable ride. Compare different compensators and choose one that gives most comfortable ride. Ideally one would like that on encountering a step disturbance the output does not overshoot too much from the steady state and settles to steady state quickly. Make suitable assumptions with respect to performance specifications.

In your response, show simulation diagrams wherever required. Along with your response also attach programs written by you in a zipped file.

Solution is in pdf.

ELL225 Q2 Assignment.pdf

Comment:

Q.2.1 4 marks

Q.2.2 8 marks

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