University of São Paulo

São Carlos School of engineering

Sistemas de Controle

List 2

Professor: Adriano Siqueira

Student: Jhon Charaja

São Carlos - Brasil

2021 - 2

1 Question 1

Figure 1 describes the block diagram of a close-loop system. In this figure, the control variable is flow output, control is performed by a human operator, and sensor are flowmeter and human operator's eyes.

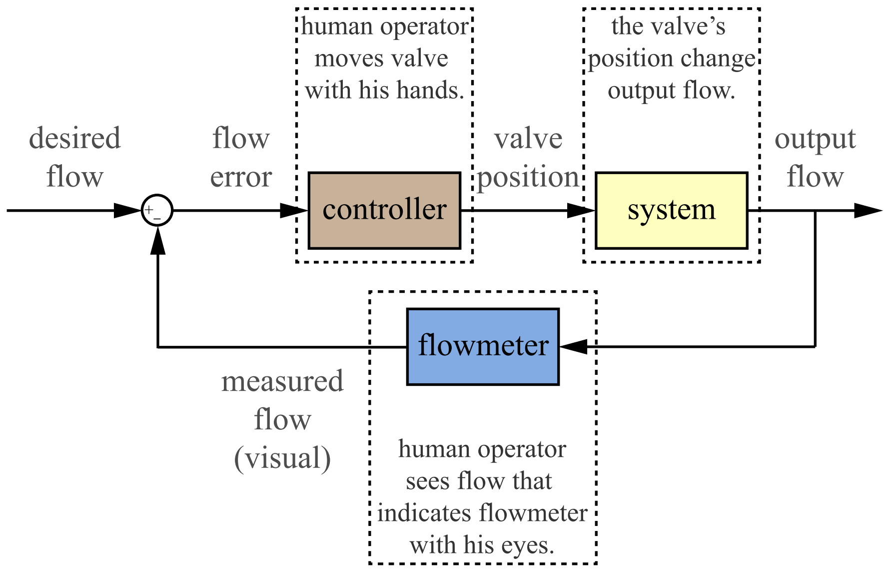

Figure 1: Block diagram that describes a human operator controlling the flow output.

2 Question 2

I will add an electric circuit that relates the current generated by the photocell with light intensity. In this way, the system will know in which direction should move to get more light.

3 Question 3

The water level remains constant because every time a drop of water comes out from the left and the buoy lowers, it causes a drop of water to enter from above and the buoy to rise again. This behavior is cyclical and is a characteristic of the mechanical system. Therefore, considering the water level as a control variable, the closed-loop system is stable.

4 Question 4

Figure 2 describes the block diagram for robot end-effector position control. The sensor block is formed by an encoder and forward kinematics. The encoder measures joint velocity and position, and forward kinematics relates joint configuration with end-effector position and orientation. Therefore, sensor block is one of the most important due to providing the feedback signal to the close-loop system.

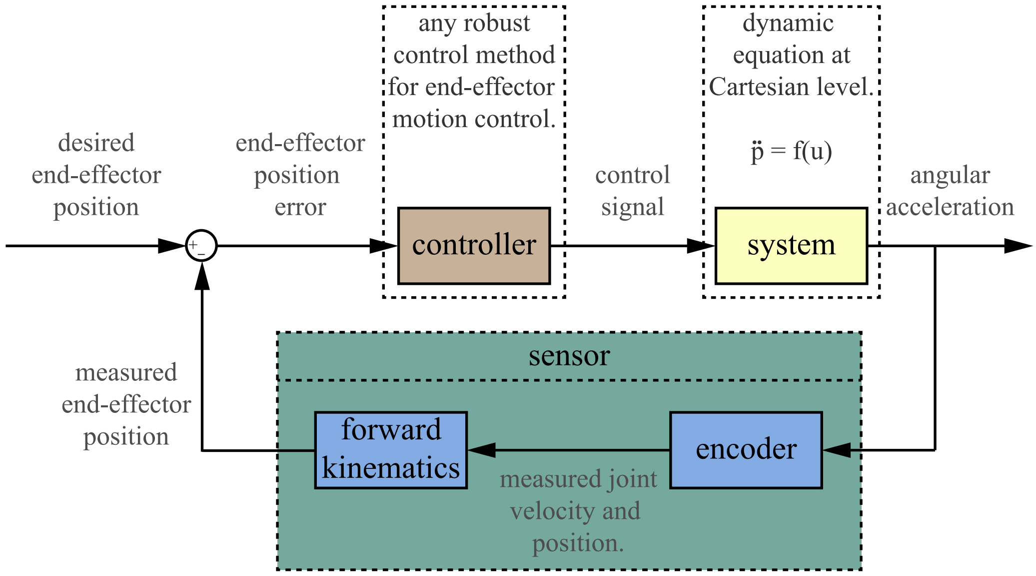

Figure 2: Block diagram for robot end-effector position control.

5 Question 5

Figure 3 describes the response of system $G(s) = \frac{1}{s}$ with a dock breaker input signal.

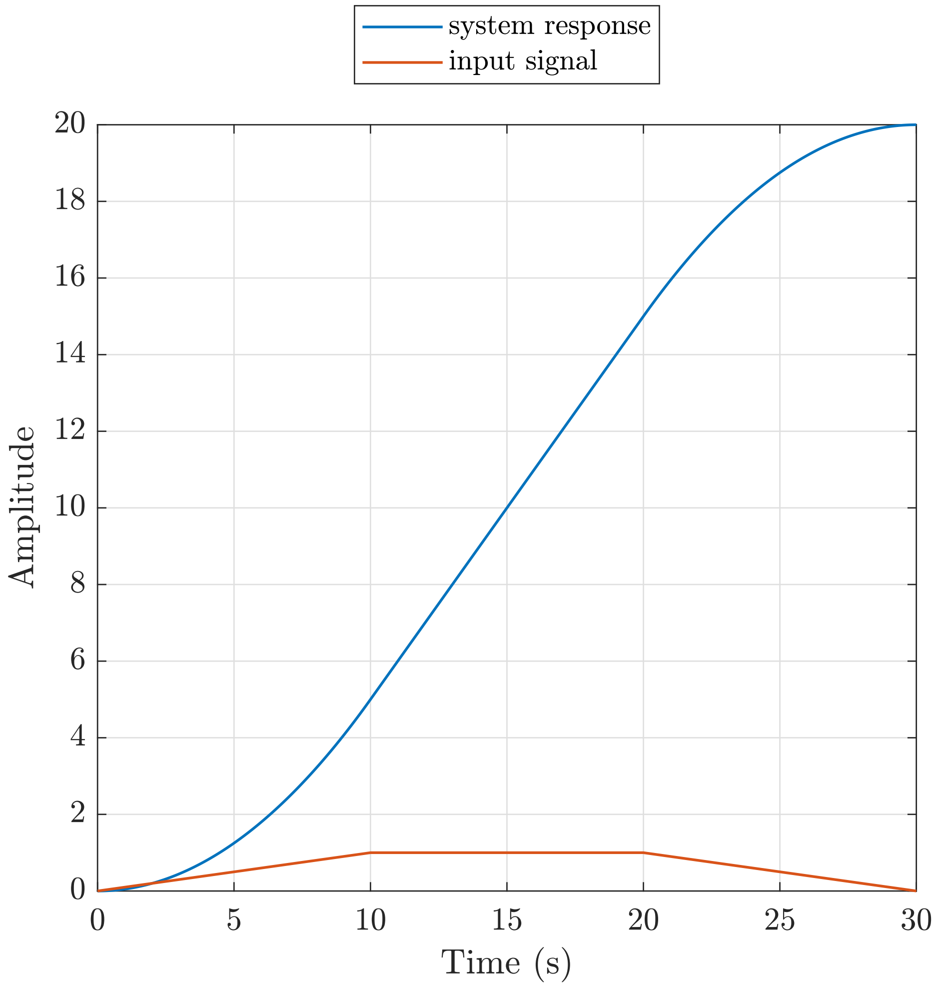

Figure 3: Response of system $G(s) = \frac{1}{s}$ with a dock breaker input signal.

6 Question 6

(a) The dynamic equation of mechanical system formed by a mass block, spring and damper is given by

$$M\ddot{x}_m = F_m - B_m\dot{x}_m - F_l, \tag{1}$$

where M is system mass, x_m is block position, F_m control force, B_m is damping constant and F_l is force generated by spring. Then, (1) can be represented in Laplace space as

$$(Ms^2 + B_m s)X_m(s) = F_m(s) - F_l(s). \tag{2}$$

The force generated by spring can be computed as $F_l = k(x_m - x_l)$, where k is spring constant and x_l is load position. Hence, considering $X_m(s) = \frac{F_l(s)}{k} + X_l(s)$, (2) can be described in terms of $F_m(s)$, $F_l(s)$ and $X_l(s)$

$$F_l(s) = \frac{k}{Ms^2 + B_m s + k}F_m(s) - \frac{Mks^2 + B_m ks}{Ms^2 + B_m s + k}X_l(s). \tag{3}$$

Finally, $G_1(s) = \frac{k}{Ms^2+B_m s+k}$ and $G_2(s) = -\frac{Mks^2+B_m ks}{Ms^2+B_m s+k}$.

(b) Figure 4 describes the block diagram for force control of mechanical system $\frac{F_l(s)}{F_m(s)} = \frac{k}{Ms^2+B_m s+k}$.

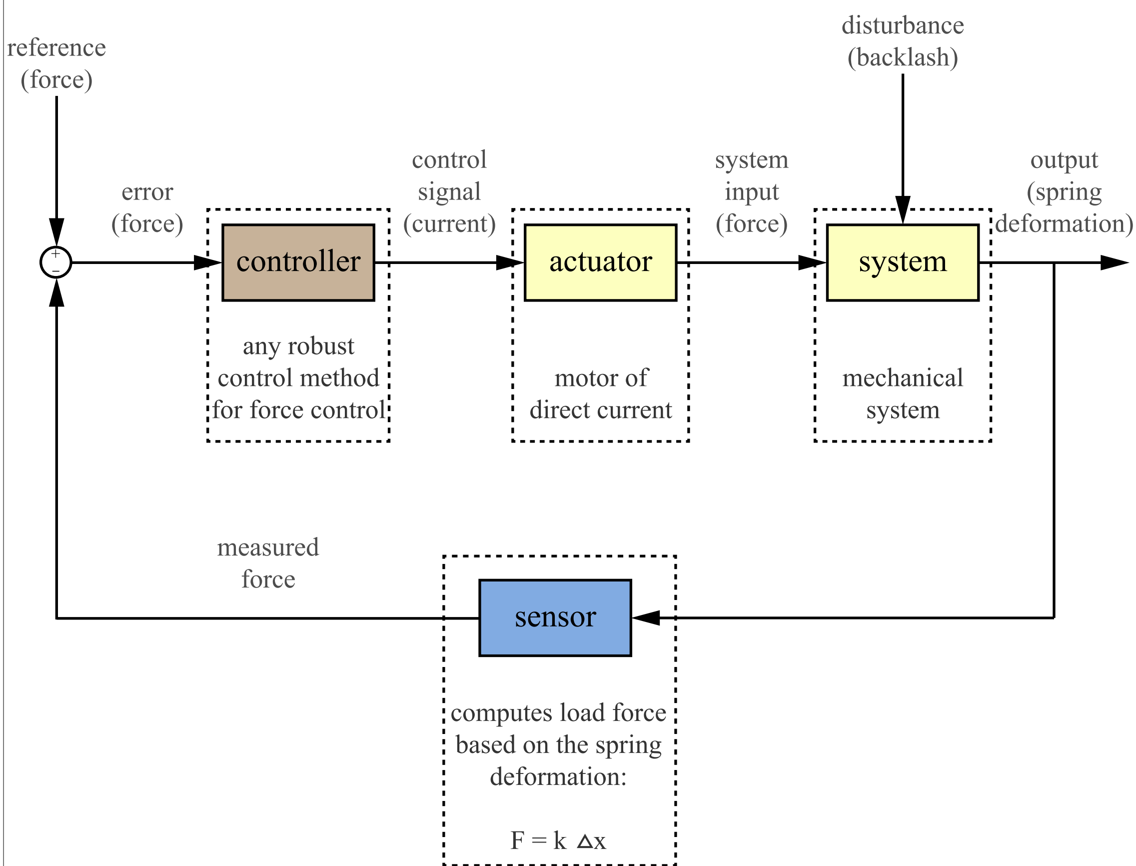

Figure 4: Block diagram for force control.

(c) Figure 5 describes step response of open-loop system ($G_1(s) = \frac{k}{Ms^2+B_m s+k}$).

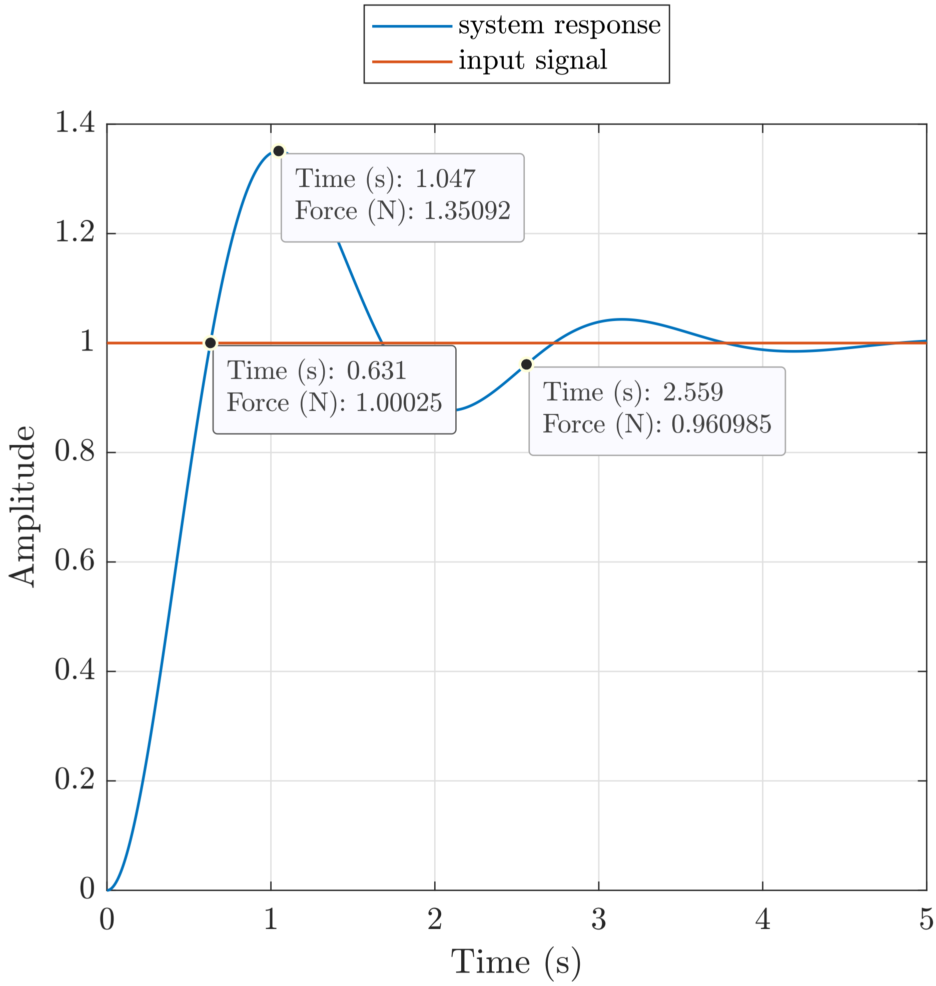

Figure 5: Step response of open-loop system ($G_1(s) = \frac{k}{Ms^2+B_m s+k}$).

(d) The step response indicates that overshoot is $\%PO \approx 35\%$, peak time is $t_p \approx 1.05$ s, rise time is $t_r \approx 0.63$ s and settling time is $t_s \approx 2.55$ s. The theoretical values indicates that overshoot is $\%PO = 35.09\%$, peak time is $t_p \approx 1.0472$ s, rise time is $t_r \approx 0.6308$ s and settling time is $t_s \approx 3$ s. Hence, values obtained from step response are close to theoretical ones.

(e) In order to avoid damage human operator, is better have a slow response with overshoot close to $\%0$ than a fast with high forces. Hence, close-loop system should be over-damping or critically damped, in this way, $\%PO \approx 0$ and $t_s \approx 1.5$ second.