Benha University
Mechanical Engineering Department (Production)
Shoubra Faculty of Engineering
4th year (Design section) 2016/2017

Assignment (2)

1. Obtain the transfer function and draw block diagram of the differentiating circuit shown in Figure (1).

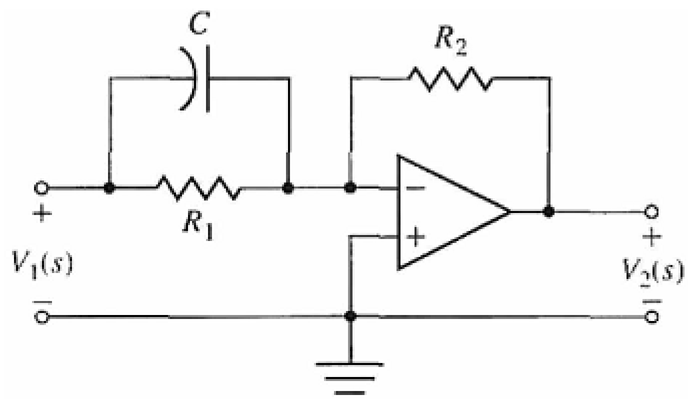


Fig. 1. A differentiating circuit

2. Figure (2) shows two pendulums suspended from frictionless pivots and connected at their midpoints by a spring. Assume that each pendulum can be represented by a mass M at the end of a massless bar of length L. Also assume that the displacement is small and linear approximations can be used for sin θ and cos θ. The spring located in the middle of the bars is unstretched when $\theta_1 = \theta_2$. The input force is represented by f(t), which influences the left-hand bar only, (a) Obtain the equations of motion, and sketch a block diagram for them, (b) Determine the transfer function $T(s) = \theta_1(s)/F(s)$.

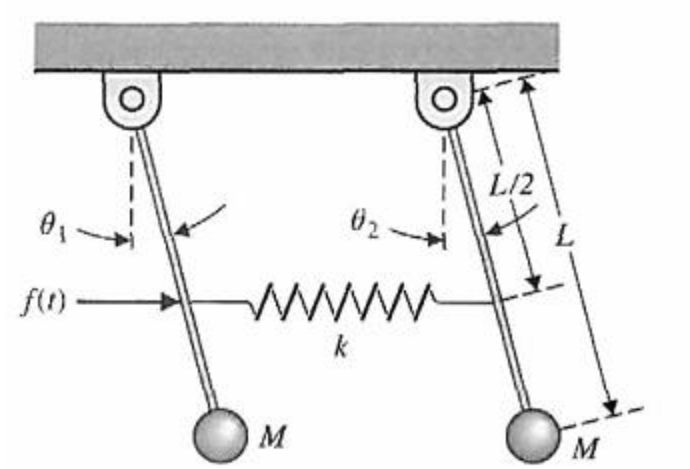


Fig. 2. The bars are each of length L and the spring is located at L/2

3. An electromechanical open-loop control system is shown in Figure (3). The generator, driven at a constant speed, provides the field voltage for the motor. The motor has an inertia J_m and bearing friction b_m. Obtain the transfer function $\theta_L(s)/V_f(s)$ and draw a block diagram of the system. The generator voltage v_g can be assumed to be proportional to the field current i_f.

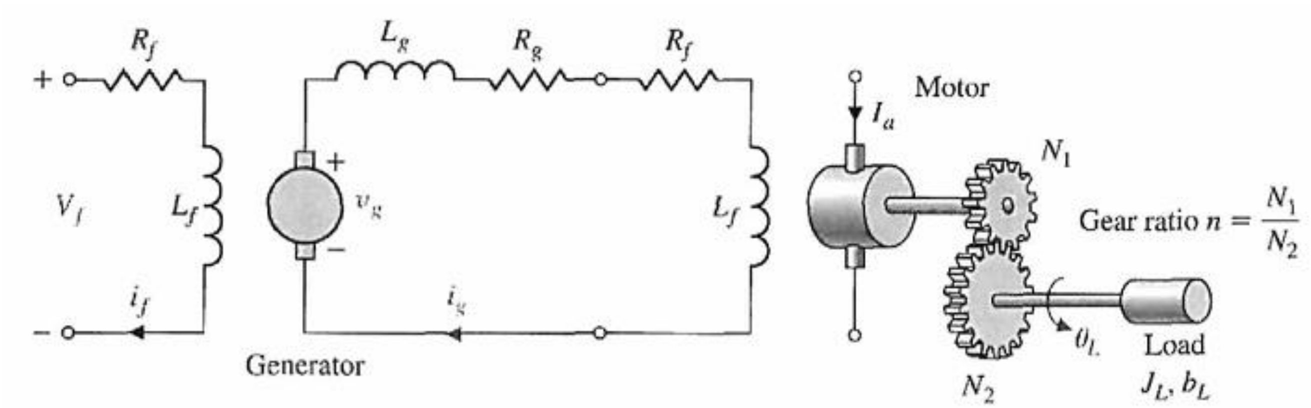


Fig. 3. Motor and generator

4. The circuit shown in Figure (4) is called a lead lag filter.

a. Find the transfer function $V_2(s)/V_1(s)$. Assume an ideal op-amp.

b. Determine $V_2(s)/V_1(s)$ when R1 = 100Ω, R2 = 200 Ω, C1= 1 µF, and C2 = 0.1 µF.

c. Determine the partial fraction expansion for $V_2(s)/V_1(s)$.

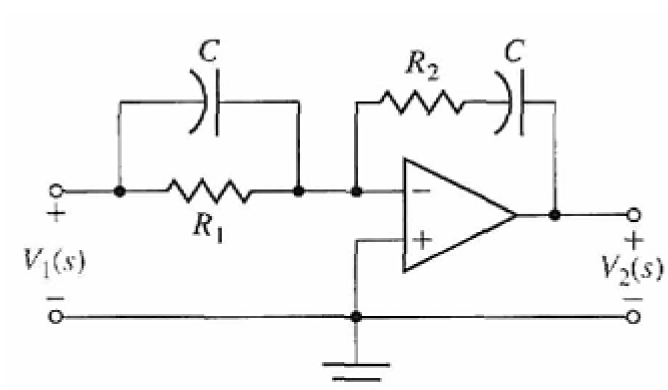


Fig. 4. Lead-lag filter

5. Derive the transfer functions for the operational amplifier circuits shown in Figure (5).

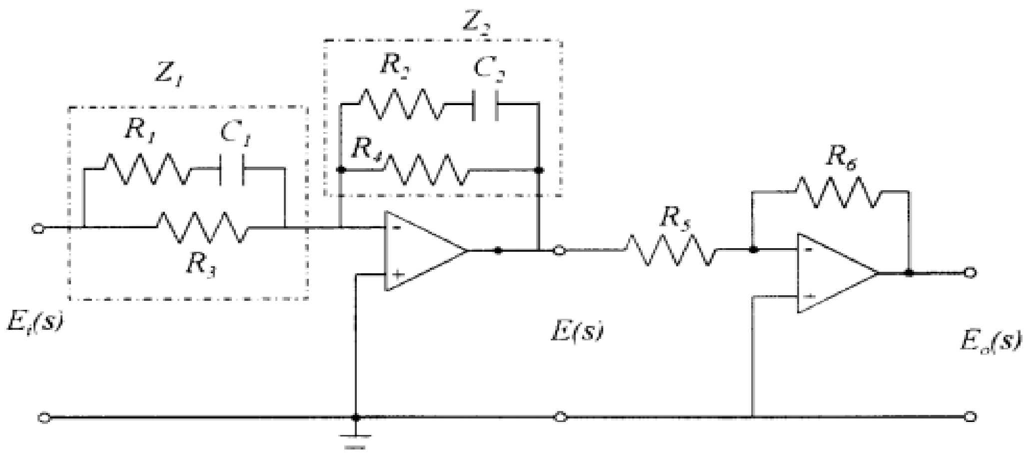


Fig. 5. Operational amplifier

6. Determine a state-space representation for the system shown in Figure (6). The motor inductance is negligible, the motor constant is K_m = 10, the back electromagnetic force constant is K_b = 0.0706, the motor friction is negligible. The motor and valve inertia is J = 0.006, and the area of the tank is 50 m^2. Note that the motor is controlled by the armature current i_a. Let x1 = h, x2 = θ, and x3 = dθ/dt. Assume that q1 = 80θ, where θ is the shaft angle. The output flow is q_o = 50h(t).

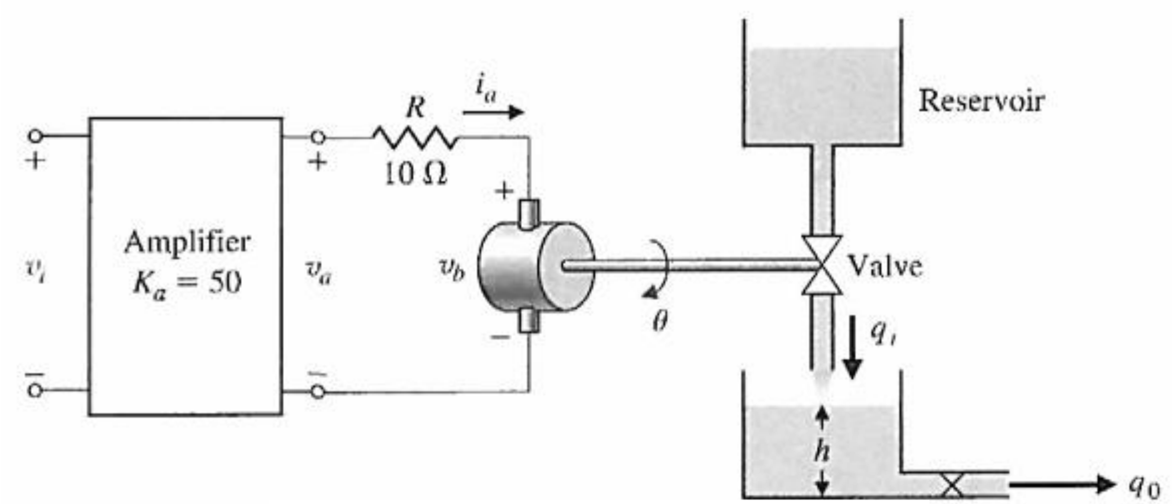
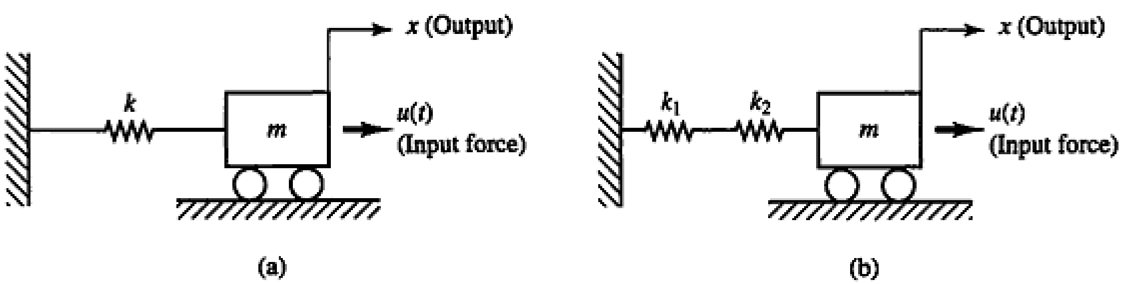


Fig. 6. One-tank system

7. Obtain state-space representations of the mechanical systems shown in Figures (7) a and b.



8. Obtain a state-space representation of the mechanical system shown in Figure (7). The force u(t) applied to mass m_1 is the input to the system. The displacements y and z are the outputs of the system. Assume that y and z are measured from their respective equilibrium positions.

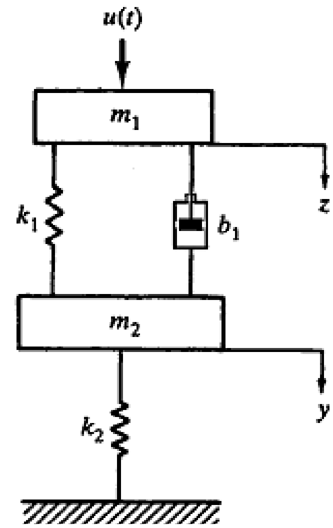


Fig. 8. Mechanical system

9. Given the state equation

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & -3 & 3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} u$$

And output equation

$$y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

Obtain the corresponding scalar differential equation in terms of y and u.

10. Obtain the unit-step response curve and unit-impulse response curve of the following system with MATLAB.

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -5 & -25 & -5 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} u$$

$$y = \begin{bmatrix} 0 & 25 & 5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + [0] u$$