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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

I SEMESTER M.TECH. (POWER ELECTRONICS & DRIVES)
END SEMESTER EXAMINATIONS, DECEMBER 2023

SUBJECT: DESIGN OF CONTROL SYSTEMS [ELE 5112]

REVISED CREDIT SYSTEM

Time: 3 Hours **Date: 30 November 2023** **MAX. MARKS: 50**

Instructions to Candidates:

- Answer **ALL** questions.
- Missing data may be suitable assumed.

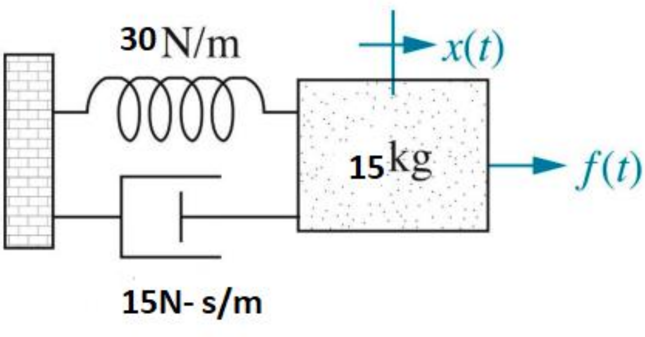
1A. Design a cascade Lag compensator using frequency domain methods, the system transfer function given as

$$G(s) = \frac{K}{s(s+1)\ \ (0.5s+1)}$$

The design specifications are steady state error constant K_V=5sec^{-1}, phase margin at least 40^o, and the gain margin at least 10dB. The new gain cross over frequency to be 0.5 rad/sec and the corresponding magnitude is 20dB. ***(03)***

1B. Design a cascade digital Lead Compensator for the open loop pulse transfer function given such that the compensated system satisfies the following specifications. The percentage overshoot 18% and a settling time of 2sec. Select suitable sampling period such that the no. of samples per cycle of damped oscillations to be 8 to 10. The open loop pulse transfer function of a system is given as $\frac{0.0176(z+0.8760)}{(z-1)(z-0.6703)}$. ***(05)***

1C. Obtain the time domain specifications settling time and percentage overshoot of the mechanical system given in Figure.



(02)

2A. The state space model of DC-DC Converter is given as

$$\dot{x} = \begin{bmatrix} -2 & 1 \\ 0 & -3 \end{bmatrix} x + \begin{bmatrix} 3 \\ 2 \end{bmatrix} \mathrm{u} \quad \text{and} \quad y = [2 \quad 3]x$$

design a state feedback controller to yield damping ratio 0.5 and natural frequency of oscillation 9 rad/sec. Use coefficient matching method. Draw the state diagram of the system with controller ***(04)***

2B. The state space model of DC-DC Converter is given as

$$\dot{x} = \begin{bmatrix} -2 & 1 \\ 0 & -3 \end{bmatrix} x + \begin{bmatrix} 3 \\ 2 \end{bmatrix} \mathrm{u} \quad \text{and } y = [2 \quad 3]x$$

The control loop yields damping ratio 0.5 and natural frequency of oscillation 9 rad/sec. Design an observer 5 times faster than the controller loop poles. Use coefficient matching method. Draw the state diagram of system with observer. ***(04)***

2C. Derive the equations for an integrator with state feedback controller. ***(02)***

3A. A Linear Time Invariant system is represented by the state equation $\dot{x} = \begin{bmatrix} -2 & 1 \\ 0 & -2 \end{bmatrix} x$. Using Lyapunov stability criterion, assess the stability of the system, and find the corresponding Lyapunov function. ***(05)***

3B. Assess the stability of non-linear systems using Lyapunov stability theory. The system is represented by the state equations. Choose a suitable Lyapunov function. Explain the associated stability theorem with mathematical equations and neat sketches.

$$\dot{x}_1 = 2x_1 + x_2$$
$$\dot{x}_2 = -x_1 + x_2^3$$

(05)

4A. For a system represented by a state space model $\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$,

$x(0) = [1 \quad 0]^T$, evaluate the minimum value of J and optimal feedback control law by designing a linear quadratic regulator using reduced matrix Riccati equation. Use the performance index satisfying state regulator problem and minimizing energy (control effort) $J = \int_0^\infty (x_1^2 + x_2^2 + u^2)\, dt \qquad Q = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, R = 1$,. Also Comment on stability of the compensated and uncompensated system. ***(07)***

4B. Derive the expression for linear quadratic regulator using Lyapunov Method and optimal control theory. ***(03)***

5A. Apply system identification methods for boost converter. ***(03)***

5B. Apply sliding mode control for a buck converter application. ***(03)***

5C. Apply power train control using model-based design. ***(04)***