DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Subject Code : IC8451
Subject Name : Control Systems
Year / Sem : II / IV

PART A – ANSWERS

UNIT I – SYSTEMS AND THEIR REPRESENTATION

1. **What is control system?**
   A system consists of number of components connected together to perform a specific function. In a system when the output quantity is controlled by varying the input quantity then the system is called control system.
2. **What are the characteristics of negative feedback?**
   - Stable circuit responses,
   - Improves stability
   - Increases the operating bandwidth of a given system,
   - The majority of all control and feedback systems is degenerative reducing the effects of the gain.
3. **Differentiate open and closed loop control system?**

Open loop control system	Closed loop control system
An open loop control system acts completely on the basis of input and the output has no effect on the control action	A closed loop control system considers the current output and alters it to the desired condition. The control action in these systems is based on the output.
An open loop control system works on fixed operation conditions and there are no disturbances.	A closed loop control system doesn't encounter and react on external disturbances or internal variations.
Open loop control systems are mostly stable.	In closed loop control systems stability is a major issue.
There is no effect on gain.	There is no-linear change in system gain.

4. **List the major advantages and disadvantages of open-loop control systems.**
   Advantages:
   - Open loop system is simple and economical
   - Construction of open loop system is easier
   - Open loop systems are generally stable

   Disadvantages:
   - Open loop systems are inaccurate and unreliable
   - The changes in the outputs due to external disturbance are not corrected automatically
5. **State the advantages of closed loop system over open loop system.**

   Advantages:
   - Closed loop control systems are more accurate even in the presence of non-linearities
   - The sensitivity of the system may be made small to make the system more stable
   - The closed loop systems are less affected by noise

   Disadvantages:

- Closed loop systems are costlier and complex
- The feedback in the closed loop system may lead to oscillatory response

6. Why negative feedback is preferred in control systems?

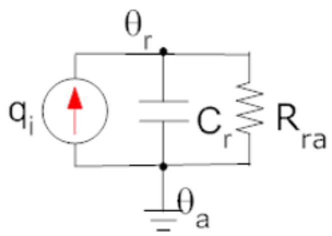
The negative feedback results in better stability in steady state and rejects any disturbance signals. It also has low sensitivity to parameter variations. Hence negative feedback is preferred in closed loop systems.

7. Write the force balance equation of ideal dashpot and ideal spring

$F_B = B\frac{dx}{dt}$; $F_K = Kx$

Where B- friction constant (N-s/m), K- spring constant (N/m), x- displacement (m)

8. Draw the electrical analog of a thermometer



Rra - The resistance of the walls between the room and the ambient
Cr - the thermal capacitance of the room
qi - the heat into the room
θr - the temperature of the room
θa - the external temperature is a constant.

9. What a ontrol systems?

Plant, Control Element, Correction Element & Measurement element.

10. Write the analogous electrical elements in force current analogy for the elements of mechanical translational system.

Mechanical Translational	Analogous electrical element (F-I)
1. Force (F)	1. Current (I)
2. Mass (M)	2. Capacitance (C)
3. Spring (K)	3. Reciprocal of Inductance (1/L)
4. Dashpot (B)	4. Reciprocal of Rsistance (1/R)
5. Linear displacement (x(t))	5. Flux (Φ = $\int V\,dt$)
6. Linear velocity (v = dx(t)/dt)	6. Voltage (V)

11. Write the analogous electrical elements in force voltage analogy for the elements of mechanical translational system.

Mechanical Translational	Analogous electrical element (F-V)
1. Force (F)	1. Voltage (V)
2. Mass (M)	2. Inductance (L)
3. Spring (K)	3. Reciprocal of capacitance (1/C)
4. Dashpot (B)	4. Resistance (R)
5. Linear displacement (x(t))	5. Charge (q = $\int i\,dt$)
6. Linear velocity (v = dx(t)/dt)	6. Current (I)

12. What are the advantages of AC servomotor?

They offer more torque per weight, efficiency, reliability and reduced radio frequency noise. And in the absence of a commutator, they require less maintenance and have a longer life expectancy.

13. Write Mason's gain Formula?

$$\frac{C(s)}{R(s)} = \frac{\sum_k p_k \Delta_k}{\Delta}$$

Where k=number of forward path, p_k=the k^{th} forward path gain

Δ = 1 − (sum of all individual loop gains) + (sum of gain products of all possible two non-touching loops) − (sum of gain products of all possible three non-touching loops) +...

Δ_k is obtained from Δ by removing the loops which are touching the ith forward path

14. What is block diagram? State its components

A block diagram is the pictorial representation of the functions performed by each component of the system and shows the flow of signals. The basic components of the block diagram are blocks, branch point and summing point

15. What is servomechanism?

Servomechanism is a feedback control system that uses error-sensing negative feedback to correct the action of a mechanism.It usually includes a built-in encoder or other position feedback mechanism to ensure the output is achieving the desired effect

16. What is a signal flow graph?

A signal flow graph is a diagram that represents a set of simultaneous algebraic equations. By taking laplace transform, the time domain differential equations governing a control system can be transferred to a set of algebraic equations in s-domain

17. Define transfer function.

A Transfer Function is the ratio of the output of a system to the input of a system, in the Laplace domain considering its initial conditions and equilibrium point to be zero.

$$Transfer\ function = \frac{C(s)}{R(s)}$$

18. What are the basic elements used for modelling mechanical translational system?

Mass(M) in kg, friction coefficient (B) in N-s/m, spring constant (K) in N/m

19. Give the different types of DC servo motors

Series DC motor, Separately excited DC motor, permanent magnet DC motor, Brushless DC motor

20. What are the disadvantages of block diagram representation?

- Block diagram does not include any information about the physical construction of the system
- Source of energy is generally not shown in the block diagram, so block diagram for a given system is not unique

UNIT II – TIME RESPONSE

1. **Define peak time and peak overshoot**

   The time taken for the response to reach the peak value for the first time is peak time.

   It is given by, $t_p = \frac{\pi}{\omega_n\sqrt{\xi^2-1}}$

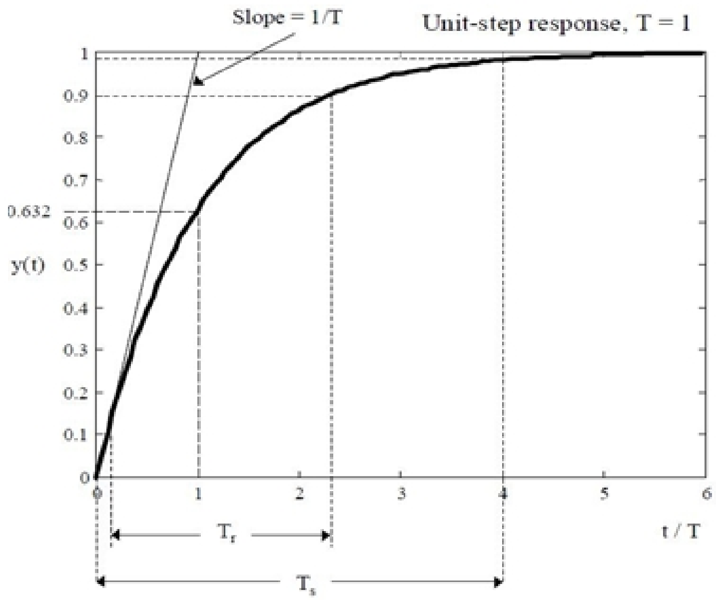
   Peak overshoot is defined as the ratio of maximum peak value measured from the Maxmium value to final value

   It is given by, $M_p\,\% = \frac{c(t_p) - c(\infty)}{c(\infty)} \times 100$

2. **List time domain specifications.**

   Rise time, delay time, peak time, peak over shoot, settling time.

3. **Draw the time response of a first order system subjected to unit step input.**

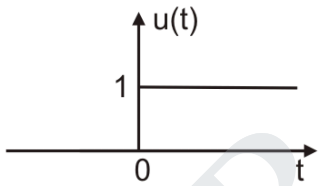


4. **Define step signal.**

The step signal is a signal whose value changes from zero to A at t= 0 and remains constant at A for t>0.

r(t) = A, t ≥ 0

0, t < 0



5. **Define settling time.**

Settling time is defined as the time taken by the response to reach and stay within specified error.

$$t_s = \frac{4}{\zeta\omega_n} \quad (for\ 2\%\ tolerance)$$

$$t_s = \frac{3}{\zeta\omega_n} \quad (for\ 5\%\ tolerance)$$

6. **What do you mean by peak over shoot?**

Peak overshoot is defined as the ratio of maximum peak value measured from the Maxmium value to final value

It is given by, $M_p\ \% = \frac{c(t_p) - c(\infty)}{c(\infty)} \times 100$

7. **Determine the type and order of the system,** $G(s)H(s) = 10/[s^3(s^2 + 2s + 1)]$

Type: 3, Order: 5

8. **List the standard test signals used in analysis of control system.**

The standard test signals employed for time domain studies are 1. step signal, ramp signal, parabolic signal, impulse signal.

9. **What is type number of a system? What is its significance?**

The type number is given by number of poles of loop transfer function at the origin. The type number of the system decides the steady state error

10. **How do you find the type of a system**

The type number of a system is essentially the number of poles at the origin of the s plane.

For the transfer function, $G(s)H(s) = \frac{(s+z_1)(s+z_2)\ .\ .\ .}{s^n(s+P_1)(s+P_2)\ .\ .\ .}$

Type number - n

11. **What is the use of Nichols chart?**

1. It is used to find the closed loop frequency response from open loop frequency response.
2. Frequency domain specifications can be determined from Nichols chart.
3. The gain of the system can be adjusted to satisfy the given specification

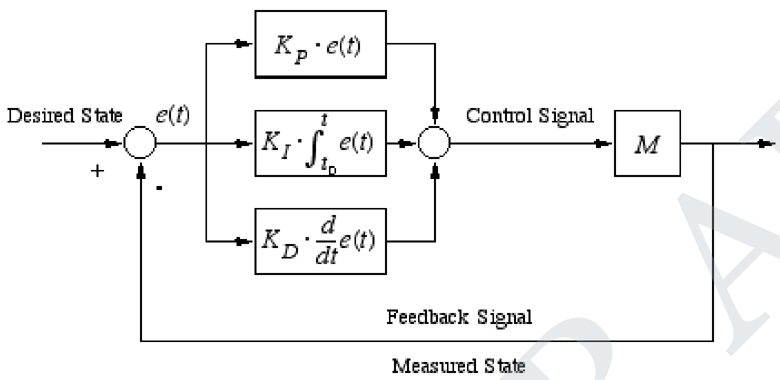
12. Distinguish between type and order

Type number of a system indicates the number of poles at the origin whereas the order of the system indicates the order of the differential equation governing the dynamics of a system. (or highest degree of denominator polynomial of the transfer function.

13. What are the effects of PI controller?

The PI controller is increases the order of the system by one, which results in reducing the steady state error. But the system becomes less stable than the original system.

14. Draw the functional block diagram of PID controller.



15. Distinguish between steady state and transient response of the system.

The output variation during the time, it takes to achieve its final value is known as transient response. The time required to achieve the final value is called transient response. The transient response may be oscillatory or exponential in nature. Steady state response is that part of the time response which remains after complete transient response vanishes from the system output.

16. Define steady state error of the system

The difference between the desired output and the actual output of the system is called steady state error, which is indicates the accuracy and plays an important role in designing the system.

$$e_{ss} = \lim_{t\to\infty} e(t) = \lim_{s\to 0} s\,E(s)$$

17. What are the advantages of generalized error coefficients?

- Used to find error as a function of time
- Error value for any type of input other than standard signal can be found

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18. **State the basic properties of root locus**

- The root locus has a number of branches that is equal to the number of Open loop poles, i.e., of G(s)
- The root locus is symmetric with respect to the real axis.

19. **Give the relation between static and dynamic error coefficients**

Static error coefficients provide the error for a standard type of inputs only. Error coefficients can be zero, constant or infinity.

The generalized error coefficient provides a simple way of estimating error signal to arbitrary inputs and the steady sate error without solving the system differential equation.

20. **What are generalized error coefficients?**

The generalized error coefficient provides a simple way of estimating error signal to arbitrary inputs and the steady sate error without solving the system differential equation.

The generalized error series is given by

The coefficients C_0, C_1, C_2,…,C_n are called generalized error coefficients or dynamic error coefficients.

21. **What do you mean by characteristic equation? Why that name?**

Denominator polynomial equation of a closed loop transfer function is called characteristic equation. The roots of the characteristic equation decides the stability of a system which in turn the characteristics of a system and hence it is called so.

22. **Find the unit impulse response of a system G(S)=5/(S+4) with zero initial condition**

R(s) = 1

C(s)/R(s) = G(s) / 1+G(s) H(s)

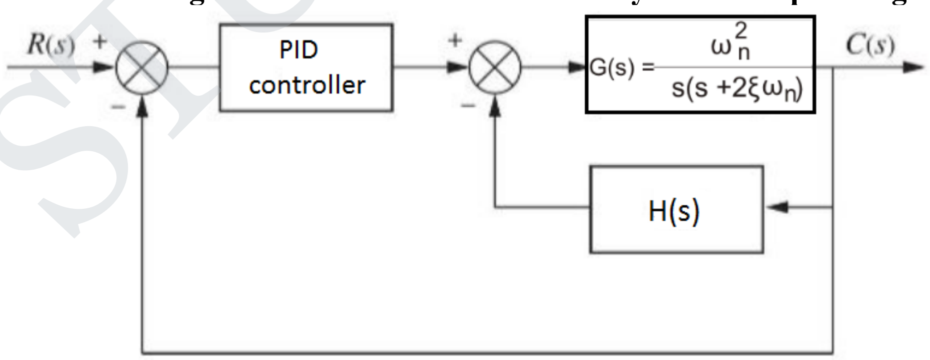
= 5/(s+9)

C(s) = 5/(s+9)

Taking laplace transform,

$c(t) = 5.e^{-9t}$

23. **Draw the block diagram of a second order control system incorporating PID control**



24. **What is the effect on system performance when a proportional controller is introduced in a system?**

- It decreases the rise time
- By varying K_p, steady state error decreases to a certain extent. Further increase in K_p leads to overshoot of system response
- It causes oscillation in system response

UNIT III – FREQUENCY RESPONSE

1. **Define the terms: 'resonant peak' and 'resonant frequency'.**
The maximum value of the magnitude is known as resonant peak.

$$M_r = \frac{1}{2\zeta\sqrt{1-\zeta^2}}$$

Frequency at which resonant peak occur is known as resonant frequency.

$$\omega_r = \omega_n\sqrt{1-2\zeta^2}$$

2. **The damping ratio and the undamped natural frequency of a second order system are 0.5 and 5 respectively. Calculate the resonant frequency.**
Given, ζ=0.5, ω_n=5

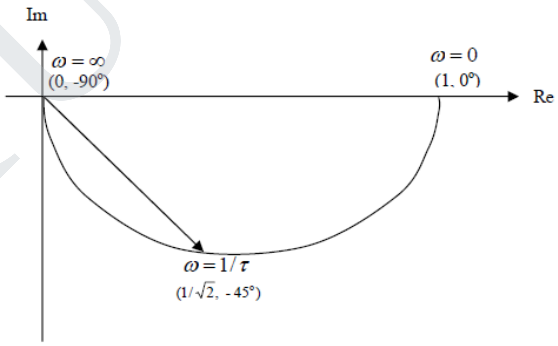
$$\omega_r = \omega_n\sqrt{1-2\zeta^2}$$

$$\omega_r = 5\sqrt{1-2(0.5)^2} \quad = 3.5355\ rad/sec$$

3. **What is corner frequency?**
The frequency at which the two asymptotes cuts or meet each other is known as break frequency or corner frequency
For first order system, $G(s) = {}^{1}/_{1+\tau s}$
Corner frequency = ${}^{1}/_{\tau}$

4. **Define gain and phase margin.**
Gain Margin
The gain margin (GM) is the factor by which the gain is less than the neutral stability value. We can usually read the gain margin directly from the bode plot. This is done by calculating the vertical distance between the $|KG(j\omega)|$ curve and the $|KG(j\omega)| = 1$ at the frequency where $\angle G(j\omega) = 180°$
Phase Margin
Phase margin (PM) is a way to measure how well stability conditions are met in a given system. Phase margin is determined by how much the phase of $G(j\omega)$ exceeds $-180°$ when $|KG(j\omega)| = 1$

5. **Draw the polar plot of G(s) =1 / (1+sT). (May 2015)**



6. **What is meant by frequency response?**
Frequency response is the quantitative measure of the output of a system or device in response to a sine input, and is used to characterize the dynamics of the system. It is a measure of magnitude and phase of the output as a function of frequency, in comparison to the input.

7. **What does a gain margin close to unity or phase margin close to zero indicate?**
A gain margin close to unity or phase margin close to zero indicates that the system response is highly oscillatory.

8. **What is Bode plot?**

Bode plot is a graph of the frequency response of a system. It is usually a combination of a Bode magnitude plot ($|G(j\omega)|\ Vs\ \omega$), expressing the magnitude (usually in decibels) of the frequency response, and a Bode phase plot ($\angle G(j\omega)\ Vs\ \omega$), expressing the phase shift. Both quantities are plotted against frequency.

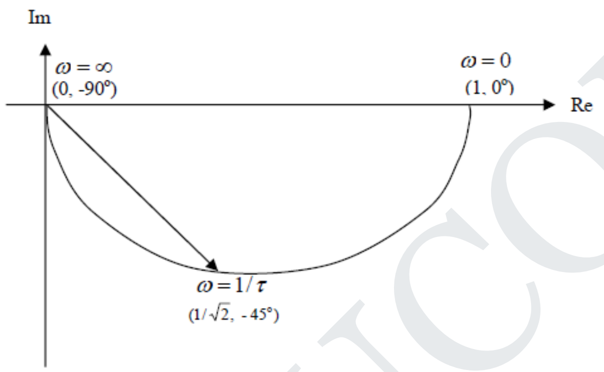
9. **What are the main advantages of Bode plot?**
   - It is based on the asymptotic approximation, which provides a simple method to plot the logarithmic magnitude curve.
   - With the help of this plot only we can directly comment on the stability of the system without doing any calculations.
   - Bode plots provides relative stability in terms of gain margin and phase margin.
   - It also covers from low frequency to high frequency range.

10. **What is Polar plot?**
    The Polar plot is a plot, which can be drawn between the magnitude and the phase angle of G(jω)H(jω) by varying ω from zero to ∞.

11. **Define Cut-off rate?**
    Cut-off rate- It is the slope of the log-magnitude curve near the cut off frequency.

12. **What is a characteristic equation?**
    The characteristic equation is the denominator of the closed-loop transfer function setting to zero (0). The roots of the equation decides the stability of the system.

13. **Draw the general shape of the polar plot of the transfer function of a Type 0 first order system**



14. **What is a constant M circle?**
    The magnitude M of closed loop transfer function with unity feedback will be in the form of circle in complex plane for each constant value of M. The family of these circles are called M circles

    Magnitude function is, $M = \frac{G(j\omega)}{1+G(j\omega)} = \frac{x+jy}{1+x+jy}$

    Then,

    $[x - \frac{M^2}{1-M^2}]^2 + y^2 = [\frac{M}{1-M^2}]^2$ is a family of circles called as M-circles.

15. **What is Nichols chart?**
    - Plot of M and N circles in gain phase plane is known as Nichols chart /plot.
    - Nyquist plot in complex plane shows how phase of transfer function and frequency variation of magnitude are related.

16. **What are the advantages of Nichols chart?**
    - Gain and phase margin can be determined easily and also graphically.
    - Closed loop frequency response is obtained from open loop frequency response.

    Gain of the system can be adjusted to suitable values.
    - Nichols chart provides frequency domain specifications.

17. **What is bandwidth?**

The bandwidth is the range of frequencies for which the system gain is more than 3 dB. The bandwidth is a measure of the ability of a feedback system to reproduce the input signal ,noise rejection characteristics and rise time

18. **Write the correlation between Phase Margin and Damping factor**

$$\varphi_m = \tan^{-1}\frac{2\zeta}{\sqrt{-2\zeta^2+\sqrt{1+4\zeta^4}}}$$

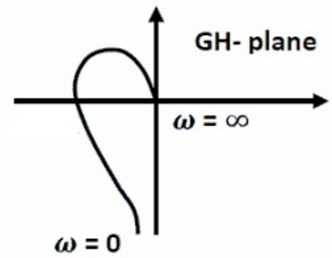
Where ζ is damping factor, φ_m is phase margin

19. **List out the different frequency domain specifications.**
    - Resonant peak
    - Resonant frequency
    - Bandwidth
    - Phase margin
    - Gain margin

20. **How is the Resonant Peak, resonant frequency, and bandwidth determined from Nichols chart?**

We can find out the gain and phase for a given frequency. Angle of positive real axis determines the phase and distance from origin of complex plane determines the gain.

21. **Show the shape of the polar plot for the transfer function K/s $(1+sT_1)(1+sT_2)$**



UNIT IV – STABILITY AND COMPENSATOR DESIGN

1. **What is the location of roots in S-plane for stability?**

When the poles of the system are located in the left-half of S-plane (LHP) and the system is not improper, then the system is said to be stable.

2. **What is meant by +20db/sec slope change**?

One decade (symbol dec) is a factor of 10 difference between two numbers (an order of magnitude difference) measured on a logarithmic scale.

3. **What are the two notions of system stability to be satisfied for a linear time – invariant system to be stable?**

A system is bounded-input, bounded-output stable (BIBO stable) if, for every bounded input, the output is finite.

The location of roots in S-plane for stability is the entire left half of the S-Plane.

4. **Why frequency domain compensation is normally carried out using the Bode plots?**

Bode plot is usually preferred to carry out the frequency domain compensation because it is easier to draw and modify. Also the gain adjustments can be conveniently carried out.

5. **State the Nyquist stability criterion**

If the Nyquist plot of the open loop transfer function G(s) corresponding to the nyquist contour in the S-plane encircles the critical point –1+j0 in the contour in clockwise direction as many times as the number of right half S-plane poles of G(s),the closed loop system is stable.

6. **State the necessary and sufficient condition for stability?**

Necessary condition for stability is that all the coefficients of the characteristic equation should be positive and real. The necessary and sufficient condition for stability is that all of the elements in the first column of the Routh array should be positive. However if anyone of them is negative the system will be unstable.

7. **Why marginally stable systems are considered unstable under the BIBO definition of stability?**

In marginally stable system, if given sinusoidal as input, output response is a sinusoidal output signal with linearly increasing amplitude. i.e, an unbounded output. Even though the input sinusoidal is bounded.

8. **The forward function of a control system is $\frac{20}{s+10}$ and its Define feedback attenuation function is $\frac{5}{s+2}$ Find the characteristics equation?**

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)H(s)} = \frac{20/(s+10)}{1+100/(s+2)(s+10)}$$

$$= \frac{20(s+2)}{s^2+12s+120}$$

Characteristic equation is $s^2+12s+120=0$

9. **What is characteristic equation?**

The denominator polynomial of the closed loop transfer function is called as characteristic equation. The residues of the polynomial equation decide the absolute stability of the system.

10. **What is dominant pole?**

The poles of the system that gives rise to the longest lasting terms in the transient response of the systems are called dominant poles. These are the poles which are closest to the $j\omega$ axis.

11. **Define BIBO stability**

A system is bounded-input, bounded-output stable (BIBO stable) if, for every bounded input, the output is finite.

12. **Define Root Loci(RL)and Root Contours(RC)**

The root locus (RL) is a systematic technique for investigating the effect of feedback on the closed-loop system poles by varying system gain K from zero to infinity.

The plot of the migration of the roots in the case of multi-parameter variations is known as root contours (RCs).

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13. **What is the effect of adding zeros?**
    - Pulls the root locus to the left, making the system more stable
    - Makes the system overall response faster
    - Rise time, peak time, decreases but overshoot increases

14. **What is the relation between φ_m and α?**

$$\sin \varphi_m = \frac{1-\alpha}{1+\alpha}$$

Where φ_m is maximum phase lead angle, α is the attenuation factor

15. What type of compensator suitable for high frequency noisy environment?

Lag Compensators has smaller bandwidth and is that less noise and other high frequency signals (often unwanted) will be passed by the system.

16. Mention the important characteristics of lead compensator.

1. Improves stability margins. It increases system bandwidth thus improving the spread of the response
2. The slope of the magnitude plot reduces at the gain crossover frequency so that relative stability improves and error decrease due to error is directly proportional to the slope.
3. Phase margin increases
4. Response becomes faster.

17. What is lag lead compensator

A lead–lag compensator is a component in a control system that improves an undesirable frequency response. A lead compensator can increase the stability or speed of response of a system; a lag compensator can reduce (but not eliminate) the steady-state error. Depending on the effect desired, one or more lead and lag compensators may be used in various combinations

18. What is the need of compensation in control systems?

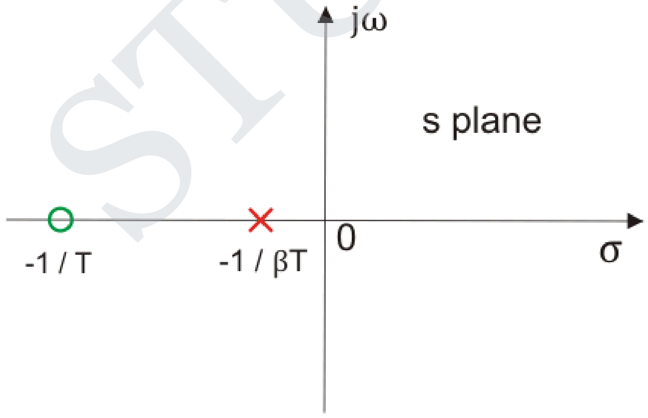
1. In order to obtain the desired performance of the system, we use compensating networks. Compensating networks are applied to the system in the form of feed forward path gain adjustment.
2. Compensate a unstable system to make it stable.
3. A compensating network is used to minimize overshoot

19. What are the different types of compensating network?

Lead Compensators, and Lag Compensators, Lag-lead Compensator system.

20. Write the transfer function of lag compensator and draw its pole-zero plots?

$$Transfer\ function = \frac{1+Ts}{1+\beta Ts}$$



21. Write the transfer function of lag-lead compensator.

$$Transfer\ function = \frac{(1+\alpha T_1 s)(1+\beta T_2 s)}{(1+T_1 s)(1+T_2 s)}$$

22. What are the effects and limitations of phase-lag control?

Effect of Phase Lag Compensation

1. Gain crossover frequency increases.
2. Bandwidth decreases.
3. Phase margin will be increase.
4. Response will be slower before due to decreasing bandwidth, the rise time and the settling time become larger.

Disadvantages (limitations) of Phase Lag Compensation

i. Due to the presence of phase lag compensation the speed of the system decreases.

23. List the advantages of phase lag network

1. Phase lag network allows low frequencies and high frequencies are attenuated.

Due to the presence of phase lag compensation the steady state accuracy increases.

24. List the advantages and disadvantages of phase lead-lag network

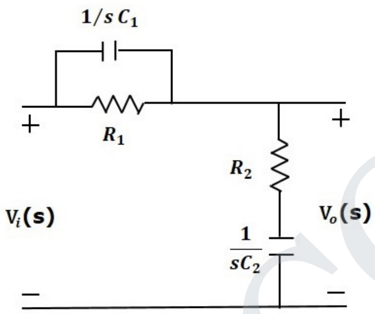
Advantages of Phase Lag Lead Compensation:

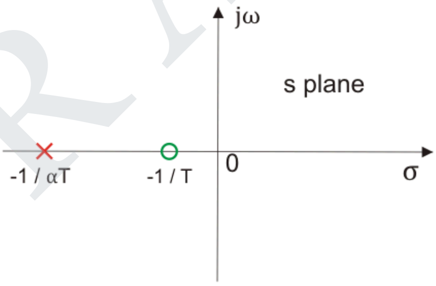
1. Due to the presence of phase lag-lead network the speed of the system increases because it shifts gain crossover frequency to a higher value.
2. Due to the presence of phase lag-lead network accuracy is improved.

Disadvantages of Phase Lag Lead Compensation

Depending upon the nominal operation design parameters of a system under an active feedback control, a lag or lead network can cause instability and poor speed and response times.

25. Draw the circuit of lead compensator and draw its pole zero diagram





UNIT V – STATE VARIABLE ANALYSIS

1. Define state variable

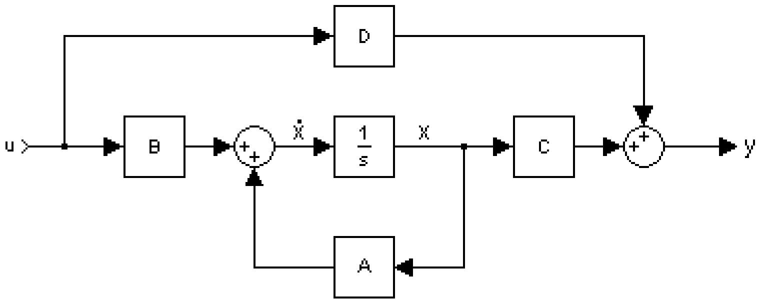
- A minimum set of variables $x_i(t)$, $i = 1, \ldots, n$, together with knowledge of those variables at an initial time t_0 and the system inputs for time $t \geq t_0$, are sufficient to predict the future system state and outputs for all time $t > t_0$.
- The state of a system describes enough about the system to determine its future behaviour in the absence of any external forces affecting the system.

2. Differentiate linear and nonlinear systems

Properties	Non-Linear	Linear
Finite Escape Time	The state of a nonlinear system can go to infinity in finite time.	This cannot happen in linear systems
Multiple Equilibria	A nonlinear system can have multiple isolated equilibrium points.	A nonlinear system can have single isolated equilibrium points.
Limit Cycles	Nonlinear systems can go into an oscillation of fixed amplitude and frequency independent of the initial conditions or linearized eigenvalues of the system.	
Periodic Oscillations	Nonlinear systems may undergo periodic excitation	Linear System dies out after transient response.

	and oscillate with frequencies that are completely unrelated to the input excitation frequency.	

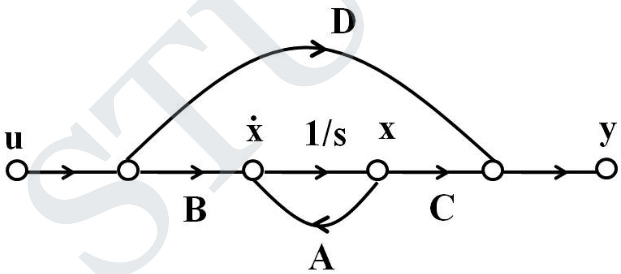
3. **For a first order differential equation described by $\dot{x}(t) = ax(t) + bu(t)$, draw the block diagram form of state diagram.**



4. **What are the advantages of state space analysis?**
   - It can be applied to non linear system.
   - It can be applied to tile invariant systems.
   - It can be applied to multiple input multiple output systems.
   - Its gives idea about the internal state of the system.
5. **What are the drawbacks in transfer function analysis?**
   - Transfer function is defined under zero initial conditions.
   - Transfer function approach can be applied only to linear time invariant systems.
   - It does not give any idea about the internal state of the system.
   - It cannot be applied to multiple input multiple output systems.
6. **What is state diagram?**

   A state diagram is a model that defines a finite set of states and behaviours and how the system transitions from one state to another when certain conditions are true.

   State diagrams are used to model complex logic in dynamic systems, from automatic transmissions to robotic systems to mobile phones
7. **Draw the signal flow representation of state model**



8. **Write the state model of nth order system?**

   State equation, $\dot{x} = Ax + Bu$

   Output equation, $y = Cx + Du$
9. **Distinguish between the following:**

   (a) **Linear & nonlinear systems (b) Time –invariant and time varying system**

   (a) Linear systems:
   - It obeys superposition principle
   - Homogeneity is applicable
   - They have single equilibrium point

   Non Linear systems:
   - It doesn't obey superposition principle
   - Homogeneity is not applicable

- They have multiple equilibrium points

(b) Time invariant systems:

- They are the systems whose output characteristics do not depend on time.
- Example: Resistance value (R) of resistor doesn't change with respect to time.

Time variant systems:

- The systems whose output characteristics depend explicitly upon time are time variant systems
- Example: mass (M) of the space shuttle vary as time increases

10. State the properties of state transition matrix

1. $\Phi(0) = I$
2. $\Phi^{-1}(t) = \Phi(-t)$
3. $x(0) = \Phi(-t)x(t)$
4. $\Phi(t_2 - t_1)\Phi(t_1 - t_0) = \Phi(t_2 - t_0)$
5. $\Phi(t)^k = \Phi(kt)$

11. State the limitations of state variable feedback.

The limitations of state variable feedback are more states are to be known. These states can either measured or estimated. This technique is insensitive to system parameter changes and external disturbances.

Practical limitations of saturations and nonlinearities must be considered when designing state variable feedback control.

12. When a system is said to be completely observable?

State model is represented by

State equation, $\dot{x} = Ax + Bu$

Output equation, $y = Cx + Du$

The state model is said to be observable if any initial state x(0) can be uniquely determined from the knowledge of output y(k) and input sequence u(k), for k=0,1,2,3,...,N, where N is some finite time. Otherwise the state model is unobservable

13. State the condition for controllability and observability of a system by Kalman's test.

The system given by,

State equation, $\dot{x} = Ax + Bu$

Output equation, $y = Cx + Du$ is completely state controllable if and only if the rank of the matrix

$C = [B \quad AB \quad A^2B \quad A^3B \; . \; . \; . \; . \; . \; A^{n-1}B]$ is n

The above system is completely state observable if and only if the rank of the matrix

$$O = \begin{bmatrix} C \\ CA \\ CA^2 \\ \vdots \\ CA^{n-1} \end{bmatrix}$$ is n

14. What is state observer?

A state observer is a system that provides an estimate of the internal state of a given real system, from measurements of the input and output of the real system

15. Write the homogeneous and non homogeneous state equation.

Homogeneous state equation : $\dot{x} = Ax$

Non homogeneous state equation : $\dot{x} = Ax + Bu$

16. Define state trajectory

It is a curve in the state space which tells about the future states resulting from a given initial state.

17. What is the necessary condition to be satisfied for design using state feedback?

The state feedback design requires arbitrary pole placements to achieve the desire performance. The necessary and sufficient condition to be satisfied for arbitrary pole placement is that the system is completely state controllable

18. What is similarity transformation?

The process of transforming a square matrix A to another similar matrix B by a transformation $P^{-1}AP = B$ is called similarity transformation. The matrix P is called transformation matrix.

19. .What is meant by diagonalization?

The process of converting the system matrix A into a diagonal matrix by a similarity transformation using the modal matrix M is called diagonalization

20. What is the need for observability test?

To check whether a system's internal states could be able to be measured from the knowledge of its external output. Most commonly used method for this test is Kalman test.