

IC 1251 CONTROL SYSTEMS

Two Marks Questions

1. What is frequency response?

A frequency response is the steady state response of a system when the input to the system is a sinusoidal signal.

2. List out the different frequency domain specifications?

The frequency domain specifications are
i) Resonant peak. ii) Resonant frequency.

3. Define –resonant Peak (M_r)?

The maximum value of the magnitude of closed loop transfer function is called resonant peak.

4. Define –Resonant frequency (f_r)?

The frequency at which resonant peak occurs is called resonant frequency.

5. 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.

6. Define Cut-off rate?

The slope of the log-magnitude curve near the cut-off is called cut-off rate. The cut-off rate indicates the ability to distinguish the signal from noise.

7. Define –Gain Margin?

The gain margin, k_g is defined as the reciprocal of the magnitude of the open loop transfer function at phase cross over frequency.
Gain margin $k_g = 1 / |G(j\omega_{pc})|$.

8. Define Phase cross over?

The frequency at which, the phase of open loop transfer functions is called phase cross over frequency ω_{pc} .

9. What is phase margin?

The phase margin, γ is the amount of phase lag at the gain cross over frequency required to bring system to the verge of instability.

11. Define Gain cross over?

The gain cross over frequency ω_{gc} is the frequency at which the magnitude of the open loop transfer function is unity..

12. What is Bode plot?

The Bode plot is the frequency response plot of the transfer function of a system.

A Bode plot consists of two graphs. One is the plot of magnitude of sinusoidal transfer function versus $\log \omega$. The other is a plot of the phase angle of a sinusoidal function versus $\log \omega$.

13. What are the main advantages of Bode plot?

The main advantages are:

- i) Multiplication of magnitude can be in to addition.
- ii) A simple method for sketching an approximate log curve is available.
- iii) It is based on asymptotic approximation. Such approximation is sufficient if rough information on the frequency response characteristic is needed.
- iv) The phase angle curves can be easily drawn if a template for the phase angle curve of $1 + j\omega$ is available.

14. Define Corner frequency?

The frequency at which the two asymptotic meet in a magnitude plot is called corner frequency.

15. Define Phase lag and phase lead?

A negative phase angle is called phase lag.
A positive phase angle is called phase lead.

16. What are M circles?

The magnitude of closed loop transfer function with unit feed back can be shown to be in the for every value if M . These circles are called M circles.

17. What is Nichols chart?

The chart consisting if M & N loci in the log magnitude versus phase diagram is called Nichols chart.

18. What are two contours of Nichols chart?

Nichols chart of M and N contours, superimposed on ordinary graph. The M contours are the magnitude of closed loop system in decibels and the N contours are the phase angle locus of closed loop system.

19. How is the Resonant Peak (M_r), resonant frequency (ω_r), and band width

determined from Nichols chart?

- i) The resonant peak is given by the value of M contour which is tangent to $G(j\omega)$ locus.

- ii) The resonant frequency is given by the frequency of $G(j\omega)$ at the tangency point.
- iii) The bandwidth is given by frequency corresponding to the intersection point of $G(j\omega)$ and -3dB M-contour .

20. What are the advantages of Nichols chart?

The advantages are:

- i) It is used to find the closed loop frequency response from open loop frequency response.
- ii) Frequency domain specifications can be determined from Nichols chart.
- iii) The gain of the system can be adjusted to satisfy the given specification.

21. What are the two types of compensation?

- i. Cascade or series compensation
- ii. Feedback compensation or parallel compensation

22. What are the three types of compensators?

- i. Lag compensator
- ii. Lead compensator
- iii. Lag-Lead compensator

23. What are the uses of lead compensator?

- 23 speeds up the transient response
- 24 increases the margin of stability of a system
- 25 increases the system error constant to a limited extent.

24. What is the use of lag compensator?

*Improve the steady state behavior of a system, while nearly preserving its transient response.

25. When is lag lead compensator is required?

The lag lead compensator is required when both the transient and steady state

response of a system has to be improved

26. What is a compensator?

A device inserted into the system for the purpose of satisfying the specifications is

called as a compensator.

26. What is Nyquist contour

The contour that encloses entire right half of S plane is called Nyquist contour.

27. State Nyquist stability criterion.

If the Nyquist plot of the open loop transfer function $G(s)$ corresponding to the

Nyquist control in the S-plane encircles the critical point $-1+j0$ in the counter

clockwise direction as many times as the number of right half S-plane poles of

$G(s)$, the closed loop system is stable.

28. Define Relative stability

Relative stability is the degree of closeness of the system, it an indication of strength or degree of stability.

29. What are the two segments of Nyquist contour?

- i. An finite line segment C_1 along the imaginary axis.
- ii. An arc C_2 of infinite radius.

30. What are root loci?

The path taken by the roots of the open loop transfer function when the loop gain is varied from 0 to ∞ are called root loci.

31. What is a dominant pole?

The dominant pole is a pair of complex conjugate pair which decides the transient response of the system.

32. What are the main significances of root locus?

- i. The main root locus technique is used for stability analysis.
- ii. Using root locus technique the range of values of K , for a stable system can be determined

33. What are the effect of adding a zero to a system?

Adding a zero to a system increases peak overshoot appreciably.

34. What are N circles?

If the phase of closed loop transfer function with unity feedback is ϕ , then $\tan \phi$ will be in the form of circles for every value of ϕ . These circles are called N circles.

35. What is control system?

A system consists of a 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.

36. What are the two major types of control system?

the two major types of control system are open loop and closed loop

37. Define open loop control system.

The control system in which the output quantity has no effect upon the input quantity are called open loop control system. This means that the output is not feedback to the input for correction.

38. Define closed loop control system.

The control system in which the output has an effect upon the input quantity so as to maintain the desired output value are called closed loop control system.

39. What are the components of feedback control system?

the components of feedback control system are plant, feedback path elements, error detector and controller.

40. Define transfer function.

The T.F of a system is defined as the ratio of the laplace transform of output to laplace transform of input with zero initial conditions.

41. What are the basic elements used for modeling mechanical translational system.

Mass, spring and dashpot

42. What are the basic elements used for modeling mechanical rotational system?

Moment of inertia J , dashpot with rotational frictional coefficient B and torsional spring with stiffness K

43. Name two types of electrical analogues for mechanical system.

The two types of analogies for the mechanical system are Force voltage and force current analogy

44. What is block diagram?

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

45. What is the basis for framing the rules of block diagram reduction technique?

The rules for block diagram reduction technique are framed such that any modification made on the diagram does not alter the input output relation.

46. What is a signal flow graph?

A signal flow graph is a diagram that represents a set of simultaneous algebraic equations

.By taking L.T the time domain differential equations governing a control system can be transferred to a set of algebraic equations in s-domain.

47. What is transmittance?

The transmittance is the gain acquired by the signal when it travels from one node to another node in signal flow graph.

48. What is sink and source?

Source is the input node in the signal flow graph and it has only outgoing branches.

Sink is an output node in the signal flow graph and it has only incoming branches.

49. Define non touching loop.

The loops are said to be non touching if they do not have common nodes.

50. Write Mason's Gain formula.

Mason's Gain formula states that the overall gain of the system is

$$T = \frac{1}{\Delta} \sum_k P_k \Delta_k$$

Δ - o.f forward paths in the signal flow graph.

P_k - Forward path gain of k th forward path

$\Delta_k = 1 - (\text{sum of individual loop gains}) + (\text{sum of gain products of all possible combinations of two non touching loops}) - (\text{sum of gain products of all possible combinations of three non touching loops}) + \dots$

Δ_k - Δ for that part of the graph which is not touching k th forward path.

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

Force-voltage e

Velocity v -current i

Displacement x -charge q

Frictional coeff B -Resistance R

Mass M - Inductance L

Stiffness K -Inverse of capacitance $1/C$

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

Force-current i

Velocity v -voltage v

Displacement x -flux ϕ

Frictional coeff B -conductance $1/R$

Mass M - capacitance C

Stiffness K -Inverse of inductance $1/L$

53. Write the force balance equation of an ideal mass element .

$$F = M \frac{d^2x}{dt^2}$$

54. Write the force balance equation of ideal dashpot element .

$$F = B \frac{dx}{dt}$$

55. Write the force balance equation of ideal spring element .

$$F = Kx$$

56. Distinguish between open loop and closed loop system

Open loop Closed loop

1. Inaccurate

2. Simple and economical

3. The changes in output due to external disturbance are not corrected

Accurate

Complex and costlier

The changes in output due to external disturbances are corrected automatically

4. They are generally stable

Great efforts are needed to design a stable system

57. What is servomechanism?

The servomechanism is a feedback control system in which the output is mechanical

position (or time derivatives of position velocity and acceleration.)

58. Why is negative feedback invariably preferred in closed loop system?

The negative feedback results in better stability in steady state and rejects any

disturbance signals.

59. What is transient response?

The transient response is the response of the system when the system changes from one

state to another.

60. What is steady state response?

The steady state response is the response of the system when it approaches infinity.

61. What is an order of a system?

The order of a system is the order of the differential equation governing the system. The

order of the system can be obtained from the transfer function of the given system.

62. Define Damping ratio.

Damping ratio is defined as the ratio of actual damping to critical damping.

63. List the time domain specifications.

The time domain specifications are

i. Delay time

ii. Rise time

iii. Peak time

iv. Peak overshoot

64. Define Delay time.

The time taken for response to reach 50% of final value for the very first time is delay

time.

65. Define Rise time.

The time taken for response to raise from 0% to 100% for the very first time is rise time.

66. Define peak time.

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

67. Define peak overshoot.

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

Maximum value to final value

68. Define Settling time.

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

69. What is the need for a controller?

The controller is provided to modify the error signal for better control action

70. What are the different types of controllers?

Proportional controller

PI controller

PD controller

PID controller

71. What is proportional controller?

It is device that produces a control signal which is proportional to the input error signal.

72. What is PI controller?

It is device that produces a control signal consisting of two terms –one proportional to error signal and the other proportional to the integral of error signal.

72. What is PD controller?

PD controller is a proportional plus derivative controller which produces an output signal consisting of two time -one proportional to error signal and other proportional to the derivative of the signal.

73 What is the significance of integral controller and derivative controller in aPID controller?

The proportional controller stabilizes the gain but produces a steady state error.

The integral control reduces or eliminates the steady state error.

74. Why derivative controller is not used in control systems?

The derivative controller produces a control action based on the rate of change of

error signal and it does not produce corrective measures for any constant error.

75. Define Steady state error.

The steady state error is defined as the value of error as time tends to infinity.

76. What is the drawback of static coefficients?

The main drawback of static coefficient is that it does not show the variation of

error with time and input should be standard input.

77. What is step signal?

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

78. What is ramp signal?

The ramp signal is a signal whose value increases linearly with time from an

initial value of zero at $t=0$. The ramp signal resembles a constant velocity.

79. What is a parabolic signal?

The parabolic signal is a signal whose value varies as a square of time from an

initial value of zero at $t=0$. This parabolic signal represents constant acceleration

input to the signal.

80. What are the three constants associated with a steady state error?

Positional error constant

Velocity error constant

Acceleration error constant

81. What are the main advantages of generalized error co-efficients?

i) Steady state is function of time.

ii) Steady state can be determined from any type of input

82. What are the effects of adding a zero to a system?

Adding a zero to a system results in pronounced early peak to system response thereby the peak overshoot increases appreciably.

83. State-Magnitude criterion.

The magnitude criterion states that $s=s_a$ will be a point on root locus if for that value of s , $|D(s)| = |G(s)H(s)| = 1$

84. State - Angle criterion.

The Angle criterion states that $s=s_a$ will be a point on root locus for that value of s , $\angle D(s) = \angle G(s)H(s) = \text{odd multiple of } 180^\circ$

85. What is a dominant pole?

The dominant pole is a pair of complex conjugate pair which decides the transient response of the system.

86. What is stepper motor?

A stepper motor is a device which transforms electrical pulses into equal

increments of rotary shaft motion called steps.

87. What is servomotor?

The motors used in automatic control systems or in servomechanism are called servomotors. They are used to convert electrical signal into angular motion.

88. Name the test signals used in control system

the commonly used test input signals in control system are impulse step ramp acceleration and sinusoidal signals.

89. Define BIBO stability.

A linear relaxed system is said to have BIBO stability if every bounded input results in a bounded output.

90. What is the necessary condition for stability.

The necessary condition for stability is that all the coefficients of the characteristic polynomial be positive.

91. What is the necessary and sufficient condition for stability.

The necessary and sufficient condition for stability is that all of the elements in the first column of the routh array should be positive.

92. What is quadrantal symmetry?

The symmetry of roots with respect to both real and imaginary axis called quadrantal symmetry.

93. What is limitedly stable system?

For a bounded input signal if the output has constant amplitude oscillations Then the system may be stable or unstable under some limited constraints such a system is called limitedly stable system.

94. What is synchros?

A synchros is a device used to convert an angular motion to an electrical signal or viceversa.

95. What is steady state error?

The steady state error is the value of error signal $e(t)$ when t tends to infinity.

96. What are static error constants.

The K_p K_v and K_a are called static error constants.

97. What is the disadvantage in proportional controller?

The disadvantage in proportional controller is that it produces a constant steady state error.

98.What is the effect of PD controller on system performance?

The effect of PD controller is to increase the damping ratio of the system and so the peak overshoot is reduced.

99.Why derivative controller is not used in control system?

The derivative controller produces a control action based on rate of change of error signal and it does not produce corrective measures for any constant error. Hence

derivative controller is not used in control system

100.What is the effect of PI controller on the system performance?

The PI controller 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.

Sixteen Marks Questions

1. For a given mechanical or electrical or electromechanical system derive the transfer function.
 - Free body diagram
 - Differential equation
 - Transfer function
- 2.Determination of the overall transfer function using Block diagram reduction technique.
 - Reduction of block diagram
 - Determination of Transfer function
3. Determination of the overall transfer function from the given signal flow graph using Mason's gain formula.
 - Reduction of signal flow graph
 - Apply masons gain formula
- 4.Write the procedure for constructing the block diagram of a given mechanical or electrical or electromechanical system.
 - Write the differential equation
 - Develop block diagram
- 5.Find the electrical analogical variables of a mechanical rotational system.
 - Write the differential equation
 - Draw the equivalent electrical network
- 6.Derive the expressions of the time domain specifications for a second order system with unit step input.
 - Time response of second order system
 - Rise time
 - Peak time
 - Peak overshoot

Settling time

7. Find the time response of a first order system for various standard inputs.

Apply the input

Solve using partial differential equation

Apply inverse Laplace transform

3. Find the time response of a second order system for unit step input.

Apply the input

Solve using partial differential equation

Apply inverse Laplace transform

8. Problems using static error coefficients or generalized error coefficients.

Find the error coefficient

Apply in formula

9. Explain the working of Synchro transmitter and receiver.

Diagram

Working principle

10. Write the rules for constructing the root locus.

Locate poles & Zeros

Find centroid & asymptotes

Find Break away or Break in points

Find crossing point in imaginary axis

11. Problems using root locus technique.

Locate poles & Zeros

Find centroid & asymptotes

Find Break away or Break in points

Find crossing point in imaginary axis

12. Stability analysis using Routh's criterion.

Construct Routh array

Check the first column for stability

13. Derive the expression for the frequency domain specifications of a second order system.

Gain Margin

Phase margin

Gain cross over frequency

Phase crossover frequency

14. Given the open loop transfer function $G(s)H(s) = 1/s(s+1)(2s+1)$ of a unity feedback system. Find the gain margin and phase margin using polar plot.

Ans: gain margin = 1.42db

phase margin = 12°

Find corner frequency

Calculate gain & phase for various values of ω

Sketch the plot

15. Write the step by step procedure for plotting the magnitude plot and phase

plot of an open loop system represented by the transfer function $G(s)$.

Find corner frequency

Calculate gain & phase for various values of ω

Sketch the plot

16. Obtain the resonant peak, resonant frequency, band width, gain margin,

phase margin of the system represented by the open loop transfer function

$G(j\omega) = 10 / j\omega(1 + 0.1j\omega)(1 + 0.05j\omega)$.

Solve by using Nicholas chart.

resonant peak = 5 db

resonant frequency = 8 rad/sec

band width = 12 rad/sec

gain margin = 8.5 db

phase margin = 30°

17. Given the open loop transfer function of a system with unity feedback, $G(s)H(s) = K/s(s+2)(s+10)$. Determine the range of K for which closed loop system is stable.

Nyquist stability criterion.

$0 < K < 240$.

18. Write the procedure for designing the lead compensator.

Find the value of K

Find the phase margin of uncompensated system

Find the new phase margin

Find new gain cross over frequency

Calculate B & T

Find $G_c(s)$

Find $G_o(s)$

Verify Phase margin

19. Write the procedure for designing the lag compensator.

Find the value of K

Find the phase margin of uncompensated system

Find the new phase margin & gain cross over frequency

Calculate α & T

Find $G_c(s)$

Find $G_o(s)$

Verify Phase margin

20. Write the procedure for designing the lag-lead compensator.

Find the value of K

Find the phase margin of uncompensated system

Find the new phase margin

Find new gain cross over frequency

Calculate $B, \omega_c, T1$ & $T2$

Find $G_c(s)$

Find $G_o(s)$

Verify Phase margin

21. Design Problems

22. Write how will you select a suitable compensator for the given system.

Ref book , "Advanced Control Theory" by Nagoor Kani, Unit I