

IC8451 – CONTROL SYSTEMS

Two Mark Question & Answers

UNIT-I

1. Define open loop control system.

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

Example: Light switch, Bread toaster, Automatic washing machine, Electric Hand drier, volume on stereo system, Tea Maker

2. 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 is called closed loop control system.

Example: Water level controller, An Air controller, cooling system in car, Automatic Electric Iron

3. Define transfer function.

The transfer function of a system is defined as the ratio of the Laplace transform of output to Laplace transform of input with zero initial conditions.

$$\text{Transfer function} = \frac{\text{Laplace transform of output}}{\text{Laplace transform of input}} \bigg|_{\text{zero initial conditions}}$$

4. 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.

5. What is the effect of positive feedback on stability?

The positive feedback increases the error signal and drives the output to instability. But sometimes the positive feedback is used in minor loops in control systems to amplify certain internal signals or parameters.

6. What are the characteristics of negative feedback?

- ✓ Rejection of disturbance signals
- ✓ Accuracy in tracking steady state value
- ✓ Low sensitivity to parameter variations.
- ✓ Reduction in gain at the expense of better stability.

7. Write Masons Gain formula.

Mason's Gain formula states that the overall gain of the system is $T = \frac{1}{\Delta} \sum_k \Delta_k P_k$

k- No. of forward paths in the signal flow graph.

P_k- Forward path gain of kth forward path

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

8. Write the force balance equation of an ideal mass element, ideal dashpot & ideal spring.

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

Ideal Dashpot: $F = B \frac{dx}{dt}$

Ideal spring element: $F = Kx$

9. What are the properties of signal flow graph?

- ✓ Signal flow graph is applicable to linear systems only.
- ✓ A node in the signal flow graph represents the variable or signal.
- ✓ A node adds the signals of all incoming branches and transmits the sum of all outgoing branches.
- ✓ The algebraic equations which are used to construct the signal flow graph must be in the form of cause and effect relationship.

10. 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. It also has low sensitivity to parameter variations. Hence negative feedback is preferred in closed loop system.

11. What are the applications of synchros?

- ✓ Fire-control system designs, remotely drive indicator gauges and as rotary position sensors for aircraft control surfaces.
- ✓ Selsyn motors were widely used in motion picture equipment to synchronize movie cameras and sound recording equipment
- ✓ Large synchros were used on naval warships, such as destroyers, to operate the steering gear from the wheel on the bridge.

12. Distinguish between open loop system and closed loop system.

Open loop system	Closed loop system
Inaccurate & unreliable	Accurate & reliable
Simple & economical	Complex & costly
Changes in output due to external disturbance are not corrected automatically	Changes in output due to external disturbance are corrected automatically
They are generally stable	Need efforts to design a stable system.
Easier to construct	Difficult to construct
More affected by noise or disturbance	Less affected by noise

UNIT-II

1. What is transient response & steady state response of a system?

The transient response is the response of the system when the system changes from one state to another.

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

2. What is the difference between type & order of a system?

Type number of a system indicates the number of poles at the origin whereas 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.

3. Define Damping ratio.

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

4. List the time domain specifications (or) what are the time domain specifications?

The time domain specifications are

- ✓ Delay time
- ✓ Rise time
- ✓ Peak time
- ✓ Peak overshoot

5. Define Delay time, Rise time, Peak time.

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

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

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

6. Define peak overshoot.

Peak overshoot is defined as the ratio of maximum peak value to the final value, where the maximum peak value is measured from the final value.

7. Define Settling time.

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

8. What is the significance of integral controller and derivative controller in a PID controller?

- ✓ The Proportional controller stabilizes the gain but produces a steady state error.
- ✓ The Integral control reduces or eliminates the steady state error.

9. 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.
- ✓ It is sensitive to noise signal and amplifies the noise.

10. 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.

11. What are the main advantages of generalized error coefficients?

- ✓ Steady state is function of time.
- ✓ Steady state can be determined from any type of input.

12. What are the standard test signals used in control systems?

The commonly used test input signals in control system are impulse, step, ramp, parabolic and sinusoidal signals.

13. What are the advantages & disadvantages of proportional controller?

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

Advantage:

- Improves disturbance signal rejection
- Improves stability of the system
- Increases the loop gain of the system

14 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.

15. 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.

16. How a control system is classified depending on the value of damping?

$\xi=0$; Undamped system

$0 < \xi < 1$; Under damped system

$\xi=1$; Critically damped system

$\xi > 1$; Over damped system

17. What is steady state error?

It is the difference between desired output & actual output of the system as t tends to infinity.

UNIT-III

1. List out the different frequency domain specifications.

The frequency domain specifications are

Resonant peak, Resonant frequency, Bandwidth, Cut-off rate, Gain Margin, Phase Margin

2. Define resonant Peak (M_r) & resonant frequency (ω_r)

The maximum value of the magnitude of closed loop transfer function is called Resonant Peak.

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

3. 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.

4. 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.

5. 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.

$$\text{Gain margin, } K_g = \frac{1}{|G(j\omega_{pc})|}$$

6. Define Phase cross over frequency.

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

7. What is Phase margin?

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

$$\text{Phase margin, } \gamma = 180^\circ + \phi_{gc}$$

8. Define Gain cross over frequency.

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

9. 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 $\log \omega$.

10. Define Corner frequency.

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

11. What are M circles?

The magnitude of closed loop transfer function with unit feedback can be shown for every value of M. These circles are called M circles.

11. What is Nichols chart?

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

12. 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.

13. How closed loop frequency response is determined from the open loop frequency using M & N circles?

The $G(j\omega)$ locus or polar plot of open loop system is sketched on the standard M and N circles chart. The meeting point of M circle with $G(j\omega)$ locus gives the magnitude of closed loop system. The meeting point of $G(j\omega)$ locus with N-circle gives the value of phase of closed loop system.

14. What are the uses of lead compensator?

- i. Speeds up the transient response
- ii. Increases the margin of stability of a system
- iii. Increases the system error constant to a limited extent.

15. What is a compensator?

A device inserted into the system for the purpose of satisfying the specifications is called as a compensator.

UNIT-IV

1. 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.

2. Define Relative stability.

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

3. What are the two segments of Nyquist contour?

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

4. 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.

5. What is a dominant pole?

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

6. 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.

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

Adding a zero to a system increases peak overshoot appreciably.

8. Define stability.

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

9. What is the relationship between Stability and coefficient of characteristic polynomial?

If the coefficient of characteristic polynomial are negative or zero, then some of the roots lie on the negative half of the S -plane. Hence the system is unstable. If the coefficients of the Characteristic polynomials are positive and if no coefficient is zero then there is a possibility of the system to be stable provided all the roots are lying on the left half of the S -plane.

10. What is Routh stability criterion?

Routh criterion states that the necessary and sufficient condition for stability is that all of the elements in the first column of the routh array is positive. If this condition is not met, the

system is unstable and the number of sign changes in the elements of the first column of routh array corresponds to the number of roots of characteristic equation in the right half of the S-plane.

11. 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.

12. What is a principle of argument?

The principles of arguments states that let $F(S)$ are analytic function and if an arbitrary closed contour in a clockwise direction is chosen in the S-plane so that $F(S)$ is analytic at every point of the contour. Then the corresponding $F(S)$ plane contour mapped in the $F(S)$ plane will encircle the origin N times in the anti clockwise direction, where N is the difference between number of poles and zeros of $F(S)$ that are encircled by the chosen closed contour in the S plane.

13. What are break away and break in points?

At break away point the root locus breaks from the real axis to enter into the complex plane. At break in point the root locus enters the real axis from the complex plane. To find the break away or break in points, form an equation for K from the characteristic equation and differentiate the equation of K with respect to s . Then find the roots of the equation $dK/ds = 0$. The roots of $dK/ds = 0$ are break away or break in points provided for this value of root the gain K should be positive and real.

14. What are asymptotes? How will you find angle of asymptotes?

Asymptotes are the straight lines which are parallel to root locus going to infinity and meet the root locus at infinity.

$$\text{Angles of asymptotes} = \pm 180^\circ (2q + 1)/(n-m) \quad q = 0, 1, 2, \dots, (n-m)$$

n -number of poles; m -number of zeros.

15. How will you find the root locus on real axis?

To find the root loci on real axis, choose the test point on real axis. If the total number of poles and zeros on the real axis to the right of this test point is odd number then the test point lie on the root locus. If it is even then the test point does not lie on the root locus.

16. How the roots of characteristic equation are related to stability?

If the root of characteristic equation has positive real part then the impulse response of the system is not bounded. Hence the system will be unstable. If the root has negative real parts then the impulse response is bounded. Hence the system will be stable.

17. What is the necessary condition for stability?

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

18. What are the requirements for BIBO Stability?

The requirement of the BIBO stability is that the absolute integral of the impulse response of the system should take only the finite value.

UNIT-V

1. What are the advantages of state space analysis?

It can be applied to non-linear as well as time varying systems. Any type of input can be considered for designing the system. It can be conveniently applied to multiple input multiple output systems. The state variables selected need not necessarily be the physical quantities of the system.

2. What are phase variables?

The phase variables are defined as the state variables which are obtained from one of the system variables and its derivatives.

3. Define state variable.

The state of a dynamical system is a minimal set of variables (known as state variables) such that the knowledge of these variables at $t=t_0$ together with the knowledge of the inputs for $t > t_0$, completely determines the behavior of the system for $t > t_0$.

4. Write the general form of state variable matrix.

The most general state-space representation of a linear system with m inputs, p outputs and n state variables is written in the following form:

$$\dot{X}(t) = AX + BU$$

$$Y(t) = CX + DU$$

Where X = state vector of order $n \times 1$.

U = input vector of order 1×1 .

A = System matrix of order $n \times n$.

B = Input matrix of order $n \times m$

C = output matrix of order $p \times n$

D = transmission matrix of order $p \times m$.

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

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

6. What is controllability?

A system is said to be completely state controllable if it is possible to transfer the system state from any initial state $X(t_0)$ at any other desired state $X(t)$, in specified finite time by a control vector $U(t)$.

7. What is observability?

A system is said to be completely observable if every state $X(t)$ can be completely identified by measurements of the output $Y(t)$ over a finite time interval.

8. Write the properties of state transition matrix.

The following are the properties of state transition matrix

$$\Phi(0) = e^{A \times 0} = I \text{ (unit matrix).}$$

$$\Phi(t) = e^{At} = (e^{-At})^{-1} = [\Phi(-t)]^{-1}.$$

$$\Phi(t_1 + t_2) = e^{A(t_1 + t_2)} = \Phi(t_1) \Phi(t_2) = \Phi(t_2) \Phi(t_1).$$

9. 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.

10. 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.

11. What is the need for controllability test?

The controllability test is necessary to find the usefulness of a state variable. If the state variables are controllable then by controlling (i.e. varying) the state variables the desired outputs of the system are achieved.

12. What is the need for observability test?

The observability test is necessary to find whether the state variables are measurable or not. If the state variables are measurable then the state of the system can be determined by practical measurements of the state variables.

13. State the condition for observability by Gilbert's method.

Consider the transformed canonical or Jordan canonical form of the state model shown below which is obtained by using the transformation, $X = MZ = \Lambda Z + U$

$$Y = Z + DU \text{ (Or) } = JZ + U$$

$$Y = Z + DU \text{ where } Z = CM \text{ and } M = \text{modal matrix.}$$

The necessary and sufficient condition for complete observability is that none of the columns of the matrix be zero. If any of the column is of have all zeros then the corresponding state variable is not observable.

14. State the duality between controllability and observability.

The concept of controllability and observability are dual concepts and it is proposed by kalman as principle of duality. The principle of duality states that a system is completely state controllable if and only if its dual system is completely state controllable if and only if its dual system is completely observable or vice versa.

15. What is the need for state observer?

In certain systems the state variables may not be available for measurement and feedback. In such situations we need to estimate the immeasurable state variables from the knowledge of input and output. Hence a state observer is employed which estimates the state variables from the input and output of the system. The estimated state variable can be used for feedback to design the system by pole placement.

16. How will you find the transformation matrix, P_0 to transform the state model to observable phase variable form?

- i. Compute the composite matrix for observability, Q_0
- ii. Determine the characteristic equation of the system $|\lambda I - A| = 0$.
- iii. Using the coefficients a_1, a_2, \dots, a_{n-1} of characteristic equation form a matrix, W .
- iv. Now the transformation matrix, P_0 is given by $P_0 = W Q_0^T$.

17. What is the pole placement by state feedback?

The pole placement by state feedback is a control system design technique, in which the state variables are used for feedback to achieve the desired closed loop poles.

18. How control system design is carried in state space?

In state space design of control system, any inner parameter or variable of a system are used for feedback to achieve the desired performance of the system. The performance of the system is related to the location of closed loop poles. Hence in state space design the closed loop poles are placed at the desired location by means of state feedback through an appropriate state feedback gain matrix, K .