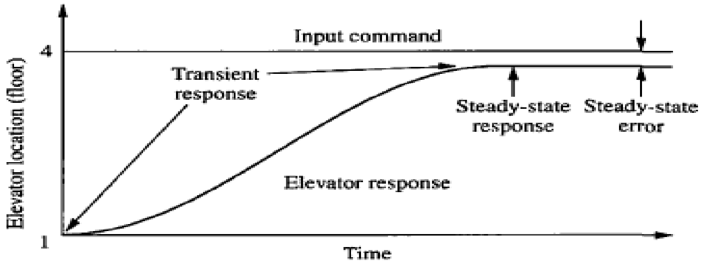
Control System Definition

Introduction

A control system consists of subsystems and processes (or plants) assembled for the purpose of obtaining a desired output with desired performance, given a specified input.

Control System Definition

- A control system consists of subsystems and processes (or plants) assembled for the purpose of obtaining a desired output with desired performance, given a specified input.
- As shows in fig. a control system in its simplest form, where the input represents a desired output. For example, consider an elevator.
- When the fourth-floor button is pressed on the first floor, the elevator rises to the fourth floor with a speed and floor-leveling accuracy designed for passenger comfort.
- The push of the fourth-floor button is an input that represents our desired output, shown as a step function in Figure 2.
- The performance of the elevator can be seen from the elevator response curve in the figure. Two major measures of performance are apparent: (1) the transient response and (2) the steady-state error.
- In our example, passenger comfort and passenger patience are dependent upon the transient response. If this response is too fast, passenger comfort is sacrificed; if too slow, passenger patience is sacrificed.
- The steady-state error is another important performance specification since passenger Safety and convenience would be sacrificed if the elevator did not properly level.



Elevator Response

Examples of Control-System Applications

- Intelligent Systems.
- Control in Virtual Prototyping and Hardware in the Loop.
- Smart Transportation Systems.
- Drive-by-wire and Driver Assist Systems
- Integration and Utilization of Advanced Hybrid Power trains
- High Performance Real-time Control, Health Monitoring, and Diagnosis
- Steering Control of an Automobile
- Idle-Speed Control of an Automobile
- Sun-Tracking Control of Solar Collectors

Title: < Control System Definition>

Description: < A control system consists of subsystems and processes (or plants) assembled for the purpose of obtaining a desired output with desired performance, given a specified input.>

Tags :< control-system-definition>

Branch: <EEE>

Question:-

1. Explain Control system?
2. Give the definition of control system in brief?

Advantages of Control Systems

Introduction

In this section we will discuss the advance control system.

Advantages of Control Systems

- With control systems we can move large equipment with precision that would otherwise be impossible.

- We can point huge antennas toward the farthest reaches of the universe to pick up faint radio signals; controlling these antennas by hand would be impossible.

- Because of control systems, elevators carry us quickly to our destination, automatically stopping at the right floor.

- We alone could not provide the power required for the load and the speed; motors provide the power, and control systems regulate the position and speed.

- We build control systems for four primary reasons:

  1. Power amplification
  2. Remote control
  3. Convenience of input form
  4. Compensation for disturbances

- For example, a radar antenna, positioned by the low-power rotation of a knob at the input, requires a large amount of power for its output rotation.

- A control system can produce the needed power amplification, or power gain-Robots designed by control system principles can compensate for human disabilities.

- Control systems are also useful in remote or dangerous locations. For example, a remote-controlled robot arm can be used to pick up material in a radioactive environment.

- Control systems can also be used to provide convenience by changing the form of the input. For example, in a temperature control system, the input is a position on a thermostat. The output is heat.

- Thus, a convenient position input yields a desired thermal output. Another advantage of a control system is the ability to compensate for disturbances.

- Typically, we control such variables as temperature in thermal systems, position and velocity in mechanical systems, and voltage, current, or frequency in electrical systems.

- The system must be able to yield the correct output even with a disturbance. For example, consider an antenna system this point in a commanded direction.

- If wind forces the antenna from its commanded position, or if noise enters internally, the system must be able to detect the disturbance and correct the antenna's position.

- Obviously, the system's input will not change to make the correction.

- Consequently, the system itself must measure the amount that the disturbance has repositioned the antenna and then return the antenna to the position commanded by the input.

Title: < advance control system >

Description: < In this section we will discuss the advance control system >

Tags :< advance-control-system >

Branch: <EEE>

Question:-

1. Give the brief description of advance control system?
2. Explain advance control system?

A History of Control Systems

Introduction

Let us now look at a brief history of human-designed control systems. Feedback control systems are older than humanity. Numerous biological control systems were built into the earliest inhabitants of our planet.

A History of Control Systems

Liquid-Level Control:-

The Greeks began engineering feedback systems around 300 a c a water clock invented by Ktesibios operated by having water trickle into a measuring container at a constant rate. The level of water in the measuring container could be used to tell time. For water to trickle at a constant rate, the supply tank had to be kept at a constant level. This was accomplished using a float valve similar to the water-level control in today's flush toilets. Soon after Ktesibios, the idea of liquid-level control was applied to an oil lamp by Philon of Byzantium

Steam Pressure and Temperature Controls

Regulation of steam pressure began around 1681 with Denis Papin's invention of the safety valve. The concept was further elaborated on by weighting the valve top. If the upward pressure from the boiler exceeded the weight, steam was released, and the pressure decreased. Kit did not exceed the weight, the valve did not open, and the pressure inside the boiler increased. Thus, the weight on the valve top set the internal pressure of the boiler. Also in the seventeenth century, Cornells Drebbel in Holland invented a purely mechanical temperature control system for hatching eggs.

Speed Control

In 1745, speed control was applied to a windmill by Edmund Lee. Increasing winds pitched the blades farther back, so that less area was available. As the wind decreased, more blade area was available. William Cubitt improved on the idea in 1809 by dividing the windmill sail into movable louvers. Also in the eighteenth century, James Watt invented the fly ball speed governor to control the speed of steam engines. In this device, two spinning fly balls rise as rotational speed increases. A steam valve connected to the fly ball mechanism closes with the ascending fly balls and opens with the descending fly balls, thus regulating the speed.

Stability, Stabilization, and Steering

In 1868, James Clerk Maxwell published the stability criterion for a third-order system based on the coefficients of the differential equation. In 1874, Edward John Routh, using a suggestion from William Kingdon Clifford that was ignored earlier by Maxwell, was able to extend the stability criterion to fifth-order systems. In 1877, the topic for the Adams Prize was "The Criterion of Dynamical Stability." In response, Routh submitted a paper entitled A Treatise on the Stability of a Given State of Motion and won the prize. This paper contains what is now known as the Routh-Hurwitz criterion for stability

Twentieth-Century Developments.

In 1922, the Sperry Gyroscope Company installed an automatic steering system that used the elements of compensation and adaptive control to improve performance. However, much of the general theory used today to improve the performance of automatic control systems is attributed to Nicholas Minorsky, a Russian born in 1885. It was his theoretical development applied to the automatic steering of ships that led to what we call today proportional-plus-integral-plus-derivative (PID), or three-mode, controllers. In the late 1920s and early 1930s, H. W. Bode and H. Nyquist at Bell Telephone Laboratories developed the analysis of feedback amplifiers. In 1948, Walter R. Evans, working in the aircraft industry, developed a graphical technique to plot the roots of a characteristic equation of a feedback system This is now known as the root locus, takes its place with the work of Bode and Nyquist in forming the foundation of linear control systems analysis and design theory.

Contemporary Applications

Today, control systems find widespread application in the guidance, navigation, and control of missiles and spacecraft, as well as planes and ships at sea. For example, modern ships use a combination of electrical, mechanical, and hydraulic components to develop rudder commands in response to desired heading commands. The rudder commands, in turn, result in a rudder angle that steers the ship. We find control systems throughout the process control industry, regulating liquid levels in tanks, chemical concentrations in vats, as well as the thickness of fabricated material. For example, consider a thickness control system for a steel plate finishing mill. Steel enters the finishing mill and passes through rollers. In the finishing mill, X-rays measure the actual thickness and compare it to the desired thickness. Any difference is adjusted by a screw-down position control that changes the roll gap at the rollers through which the steel passes. This change in roll gap regulates the thickness. Modern developments have seen widespread use of the digital computer as part of control systems. For example, computers in control systems are for industrial robots, spacecraft, and the process control industry. It is hard to visualize a modern control system that does not use a digital computer. The space shuttle contains numerous control systems operated by an onboard computer on a time-shared basis. Without control systems, it would be impossible to guide the shuttle to and from earth's orbit or to adjust the orbit itself and support life on board. Navigation functions programmed into the shuttle's computers use data from the shuttle's hardware to estimate vehicle position and velocity. This information is fed to the guidance equations that calculate commands for the shuttle's flight control systems, which steer the spacecraft. In space, the flight control system gimbals (rotates) the orbital maneuvering system (OMS) engines into a position that provides thrust in the commanded direction to steer the spacecraft.

Title: < A History of Control Systems>

Description: < Let us now look at a brief history of human-designed control systems. Feedback control systems are older than humanity. Numerous biological control systems were built into the earliest inhabitants of our planet.>

Tags :< A-History-of-Control-Systems >

Branch: <EEE>

Question:-

1. Explain, History of Control Systems?
2. Write a short note of History of Control Systems?

Open-Loop control Systems (Nonfeedback Systems)

Introduction

Open loop system is also known as non feedback system.

Open-Loop control Systems (Nonfeedback Systems)

- An open-loop control system is shown in Fig. It starts with a subsystem called an input transducer, which converts the form of the input to that used by the controller.

- The controller drives a process or a plant. The input is sometimes called the reference, while the output can be called the controlled variable.

- Other signals, such as disturbances, are shown added to the controller and process outputs via summing junctions, which yield the algebraic sum of their input signals using associated signs.

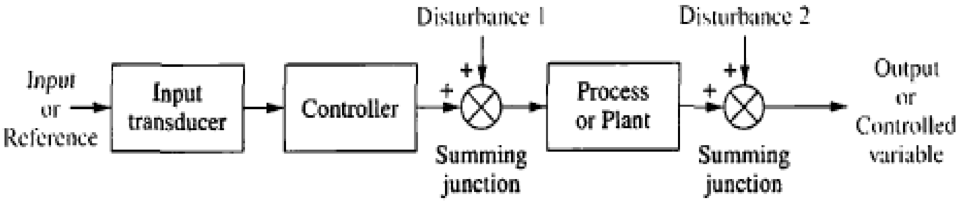


Fig. Open loop control system(Nonfeedback System)

- For example, the plant can be a furnace or air conditioning system, where the output variable is temperature. The controller in a heating system consists of fuel valves and the electrical system that operates the valves.

- Open-loop systems, then, do not correct for disturbances and are simply commanded by the input. For example, toasters are open-loop systems, as anyone with burnt toast can attest.

- The controlled variable (output) of a toaster is the color of the toast. The device is designed with the assumption that the toast will be darker the longer it is subjected to heat.

- The toaster does not measure the color of the toast; it does not correct for the fact that the toast is rye, white, or sourdough, nor does it correct for the fact that toast comes in different thicknesses.

- The distinguishing characteristic of an open-loop system is that it cannot compensate for any disturbances that add to the controller's driving signal (Disturbance 1 in Fig.).

- For example, if the controller is an electronic amplifier and Disturbance 1 is noise, then any additive amplifier noise at the first summing junction will also drive the process, corrupting the output with the effect of the noise.

- The output of an open-loop system is corrupted not only by signals that add to the controller's commands but also by disturbances at the output (Disturbance 2 in fig). The system cannot correct for these disturbances.

- Other examples of open-loop systems are mechanical systems consisting of a mass, spring, and damper with a constant force positioning the mass.

- The greater the force, the greater the displacement. Again, the system position will change with a disturbance, such as an additional force, and the system will not detect or correct for the disturbance.

Title: < Open-Loop control Systems (Nonfeedback Systems)>

Description: < Open loop system is also known as non feedback system.>

Tags :<open-loop-control-system>

Branch: <EEE>

Question:-

1. Explain Open loop control system?
2. Draw the figure of Open-Loop control Systems (Nonfeedback Systems), Explain?

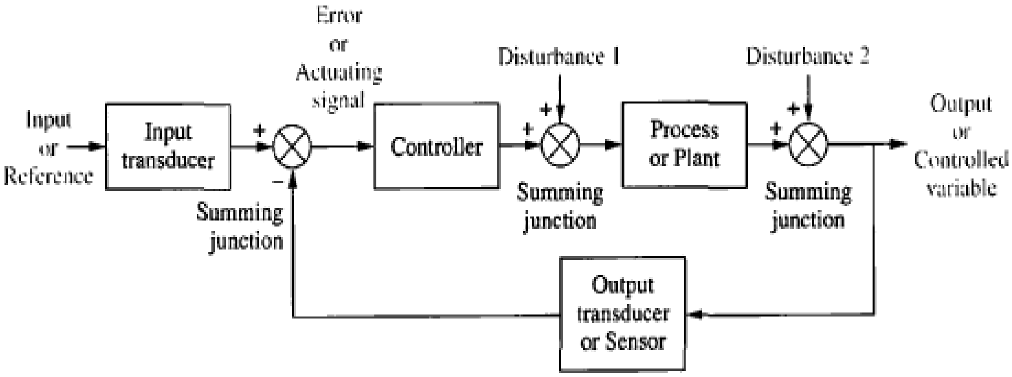
Closed-Loop Control Systems (Feedback Control Systems)

Introduction

A system with one or more feedback paths such as that just described is called a closed-loop system.

Closed-Loop Control Systems (Feedback Control Systems)

- Disadvantages of open loop control system are corrected through the close loop control system. The input transducer converts the form of the input to the form used by the controller.
- An output transducer, or sensor, measures the output response and converts it into the form used by the controller.
- For example, if the controller uses electrical signals to operate the valves of a temperature control system, the input position and the output temperature are converted to electrical signals.
- The input position can be converted to a voltage by a potentiometer, a variable resistor, and the output temperature can be converted to a voltage by a thermistor.
- A device whose electrical resistance changes with temperature. The first summing junction algebraically adds the signal from the input to the signal from the output, which arrives via the feedback path, the return path from the output to the summing junction.
- The output signal is subtracted from the input signal. The result is generally called the actuating signal.
- The closed-loop system compensates for disturbances by measuring the output response, feeding that measurement back through a feedback path, and comparing that response to the input at the summing junction.
- If there is any difference between the two responses, the system drives the plant, via the actuating signal, to make a correction. If there is no difference, the system does not drive the plant, since the plant's response is already the desired response.
- Closed-loop systems, then, have the obvious advantage of greater accuracy than open-loop systems. They are less sensitive to noise, disturbances, and changes in the environment.
- Closed-loop systems are more complex and expensive than open-loop systems.



Title: < Closed-Loop Control Systems (Feedback Control Systems)>

Description: < A system with one or more feedback paths such as that just described is called a closed-loop system.>

Tags :< Closed-Loop-Control-Systems >

Branch: <EEE>

Question:-

1. Explain Closed-Loop Control Systems?
2. Draw the figure of Closed-Loop Control Systems(Feedback Control Systems)?

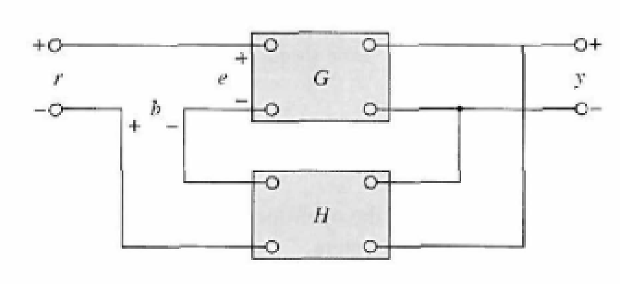
Effect of Feedback on Overall Gain

Introduction

Feedback is used to reduce the error between the reference input and the system output. Feedback also has effects on such system performance characteristics as stability, bandwidth, overall gain, impedance, and sensitivity.

Effect of Feedback on Overall Gain

- Feedback affects the gain G of a nonfeedback system by a factor of 1 + GH.
- The system of Fig. give below is said to have negative feedback, because a minus sign is assigned to the feedback signal.
- The quantity GH may itself include a minus sign, so the general effect of feedback is that it may increase or decrease the gain G.
- In a practical control system, G and H are functions of frequency, so the magnitude of 1 - GH may be greater than 1 in one frequency range but less than 1 in another.
- Therefore, feedback could increase the gain of system in one frequency range but decrease it in another.



- Feedback may increase the gain of a system in one frequency range but decrease it in another.

Title: < Effect of Feedback on Overall Gain>

Description: < Feedback is used to reduce the error between the reference input and the system output. Feedback also has effects on such system performance characteristics as stability, bandwidth, overall gain, impedance, and sensitivity.>

Tags :< Effect-of-Feedback-on-Overall-Gain >

Branch: <EEE>

Question:-

1. Explain Effect of Feedback on Overall Gain?
2. Write a short note on the Effect of Feedback on Overall Gain?

Effect of Feedback on Stability

Introduction

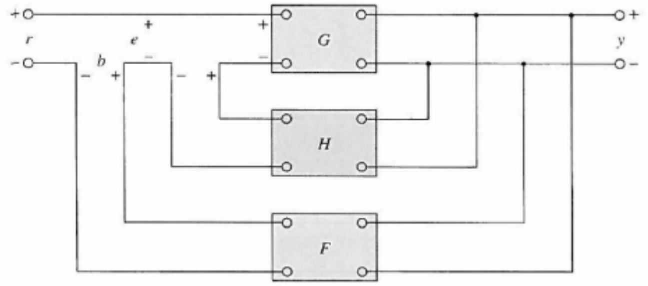
In this system we will discuss the effect of feedback on stability.

Effect of Feedback on Stability

$$M = \frac{y}{r} = \frac{G}{1 + GH}$$

Stability is a notion that describes whether the system will be able to follow the input command, that is, be useful in general. In a nonrigorous manner, a system is said to be unstable if its output is out of control. To investigate the effect of feedback on stability, from the equation above. If GH = - 1, the output of the system is infinite for any finite input, and the system is said to be unstable. Therefore, we may state that feedback can cause a system that is originally stable to become unstable. Certainly, feedback is a double-edged sword; when it is improperly used, it can be harmful. It should be pointed out, however, that we are only dealing with the static case here and in general, GH = — 1 is not the only condition for instability. It can be demonstrated that one of the advantages of incorporating feedback is that it can stabilize an unstable systemIf we introduce another feedback loop through a negative Feedback gain of F, as shown in Fig. given below, the input-output relation of the overall system is

$$\frac{y}{r} = \frac{G}{1 + GH + GF}$$



It is apparent that although the properties of G and H are such that the inner-loop feedback system is unstable, because GH = -1, the overall system can be stable by properly selecting the outer-loop feedback gain F. In practice, GH is a function of frequency, and the stability condition of the closed-loop system depends on the magnitude and phase of GH. The bottom line is that feedback can improve stability or be harmful to stability if it is not properly applied. Sensitivity considerations often are important in the design of control systems. Because all physical elements have properties that change with environment and age, we cannot always consider the parameters of a control system to be completely stationary over the entire operating life of the system. For instance, the winding resistance of an electric motor changes as the temperature of the motor rises during operation. Control systems with electric components may not operate normally when first turned on because of the still-changing system parameters during warm-up. This phenomenon is sometimes called "morning sickness." Most duplicating machines have a warm-up period during which time operation is blocked out when first turned on. In general, a good control system should be very insensitive to parameter variations but sensitive to the input commands. We shall investigate what effect feedback has on sensitivity to parameter variations. We consider G to be a gain parameter that may vary. The sensitivity of the gain of the overall system M to the variation in G is defined as

$$S_G^M = \frac{\partial M/M}{\partial G/G} = \frac{\text{percentage change in } M}{\text{percentage change in } G}$$

Where *dM* denotes the incremental change in *M* due to the incremental change in *G,* or *dG.* The sensitivity function is written

$$S_G^M = \frac{\partial M}{\partial G}\,\frac{G}{M} = \frac{1}{1 + GH}$$

This relation shows that if GH is a positive constant, the magnitude of the sensitivity function can be made arbitrarily small by increasing GH, provided that the system remains stable. It is apparent that, in an open-loop system, the gain of the system will respond in a one-to-one fashion to the variation in G. Again, in practice, GH is a function of frequency; the magnitude of 1+GH may be less than unity over some frequency ranges, so feedback could be harmful to the sensitivity to parameter variations in certain cases. In general, the sensitivity of the system gain of a feedback system to parameter variations depends on where the parameter is located. The reader can derive the sensitivity of the system in Fig due to the variation of H.

Title: < effect of feedback on stability >

Description: < In this section we will discuss the voltage regulation of generator >

Tags :< effect-of-feedback-on-stability >

Branch: <EEE>

Question:-

1. Explain effect of feedback on stability?
2. Write a short note of effect of feedback on stability?

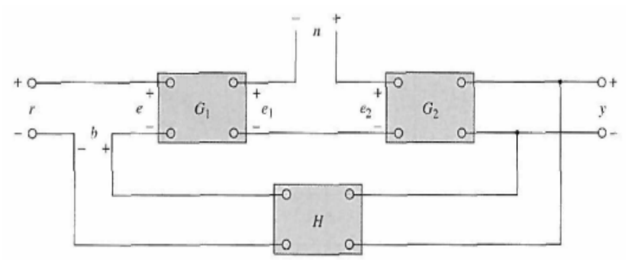
Effect of Feedback on External Disturbance or Noise

Introduction

In this section we will discuss the effect of feedback on external disturbance or noise.

Effect of Feedback on External Disturbance or Noise

- All physical systems are subject to some types of extraneous signals or noise during operation.
- Examples of these signals are thermal-noise voltage in electronic circuits and brush or commutator noise in electric motors.
- External disturbances, such as wind gusts acting on an antenna, are also quite common in control systems.
- Therefore, control systems should be designed so that they are insensitive to noise and disturbances and sensitive to input commands.
- The effect of feedback on noise and disturbance depends greatly on where these extraneous signals occur in the system.
- Feedback can reduce the effect of noise and disturbance on system performance. Let us refer to the system shown in Fig. below, in which r denotes the command



Feedback system with a noise signal.

- Signal and n is the noise signal. In the absence of feedback, that is, H= 0, the output)' due to n acting alone is

$$Y = G_{2n} \qquad (1)$$

- With the presence of feedback, the system output due to *n* acting alone is

$$Y = \frac{G_2}{1 + G1G2H} n \qquad (2)$$

- Comparing Eq. (2) with Eq. (1) shows that the noise component in the output of Eq. (2) is reduced by the factor 1 + *GxGiH* if the latter is greater than unity and the system is kept stable.
- The feedback forward and forward controller configurations are used along with feedback to reduce the effects of disturbance and noise inputs.
- In general, feedback also has effects on such performance characteristics as bandwidth, impedance, transient response, and frequency response.

Title: < feedback on external disturbance or noise>

Description: < In this section we will discuss the feedback on external disturbance or noise>

Tags :< feedback-on-external-disturbance-or-noise>

Branch: <EEE>

Question:-

1. Write a short note on feedback on external disturbance or noise?
2. Explain feedback on external disturbance or noise?

Types of feedback control system

Introduction

Feedback system is classified in two parts and we will discuss the type of feedback control system in this section.

Types of feedback control system

- Feedback control systems may be classified in a number of ways, depending upon the purpose of the classification.
- For instance, according to the method of analysis and design, control systems are classified as linear or nonlinear, and time-varying or time-invariant.
- According to the types of signal found in the system, reference is often made to continuous-data or discrete-data systems, and modulated or unmodulated systems.
- Control systems are often classified according to the main purpose of the system. For instance, a position-control system and a velocity-control system control the output variables just as the names imply.
- the type of control system is defined according to the form of the open-loop transfer function. In general, there are many other ways of identifying control systems according to some special features of the system.
- It is important to know some of the more common ways of classifying control systems before embarking on the analysis and design of these systems.

Types of Feedback control systems in given below,

1. **Linear versus Nonlinear Control Systems**

a) Linear systems satisfy the properties of superposition and homogeneity. Any system that does not satisfy these properties is nonlinear.

b) Linear systems have one equilibrium point at the origin. Nonlinear systems may have many equilibrium points

2. **Time-Invariant versus Time-Varying Systems**

a) Stability needs to be precisely defined for nonlinear systems.

b) The principle of superposition does not necessarily hold for forced response for nonlinear systems.

c) Nonlinearities can be broadly classified.

Title: < Types of feedback control system>

Description: < Feedback system is classified in two parts and we will discuss the type of feedback control system in this section.>

Tags :< Types-of-feedback-control-system >

Branch: <EEE>

Question:-

1. Explain Types of feedback control system?
2. Write a short notes on feedback control system and its types?

Linear versus Nonlinear Control Systems

Introduction

In this section we will discuss the linear versus nonlinear control system.

Linear versus Nonlinear Control Systems

- This classification is made according to the methods of analysis and design.
- Generally linear systems do not exist in practice, because all physical systems are nonlinear to some extent.
- Linear feedback control systems are idealized models fabricated by the analyst purely for the simplicity of analysis and design.
- When the magnitudes of signals in a control system are limited to ranges in which system components exhibit linear characteristics (i.e., the principle of superposition applies), the system is essentially linear.
- But when the magnitudes of signals are extended beyond the range of the linear operation, depending on the severity of the nonlinearity, the system should no longer be considered linear.
- For instance, amplifiers used in control systems often exhibit a saturation effect when their input signals become large; the magnetic field of a motor usually has saturation properties.
- Other common nonlinear effects found in control systems are the backlash or dead play between coupled gear members, nonlinear spring characteristics, nonlinear friction force or torque between moving members, and so on.
- Quite often, nonlinear characteristics are intentionally introduced in a control system to improve its performance or provide more effective control.
- For instance, to achieve minimum-time control, an on off (bang-bang or relay) type controller is used in many missile or spacecraft control systems.
- Typically in these systems, jets are mounted on the sides of the vehicle to provide reaction torque for attitude control.
- These jets are often controlled in a full-on or full-off fashion, so a fixed amount of air is applied from a given jet for a certain time period to control the attitude of the space vehicle.
- For linear systems, a wealth of analytical and graphical techniques is available for design and analysis purposes. A majority of the material in this text is devoted to the, analysis and design of linear systems.
- Nonlinear systems, on the other hand, are usually difficult to treat mathematically, and there are no general methods available for solving a wide class of nonlinear systems.
- It is practical to first design the controller based on the linear-system model by neglecting the nonlinearities of the system.
- The designed controller is then applied to the nonlinear system model for evaluation or redesign by computer simulation.
- The Virtual Lab is mainly used to model the characteristics of practical systems with realistic physical components.

Title: < linear versus nonlinear control system >

Description: < In this section we will discuss the linear versus nonlinear control system >

Tags :< linear-versus-nonlinear-control-system >

Branch: <EEE>

Question:-

1. Write a short note of linear versus nonlinear control system?
2. Explain in brief, linear versus nonlinear control system?

Time-Invariant versus Time-Varying Systems

Introduction

In this section we will discuss the Time-Invariant versus Time-Varying Systems.

Time-Invariant versus Time-Varying Systems

When the parameters of a control system are stationary with respect to time during the operation of the system, the system is called a time-invariant system. For example, the winding resistance of an electric motor will vary when the motor is first being excited and its temperature is rising. Another example of a time-varying system is a guided-missile control system in which the mass of the missile decreases as the fuel on board is being consumed during flight. Although a time-varying system without nonlinearity is still a linear system, the analysis and design of this class of systems are usually much more complex than that of the linear time-invariant systems.

Continuous-Data Control Systems

A continuous-data system is one in which the signals at various parts of the system are all functions of the continuous time variable t. The signals in continuous-data systems may be further classified as ac or dc. When one refers to an ac control system, it usually means that the signals in the system are modulated by some form of modulation scheme. A dc control system, on the other hand, simply implies that the signals are unmodulated, but they are Still ac signals according to the conventional definition. The schematic diagram of a closed loop dc control system is shown in Fig. 1-12. Typical waveforms of the signals in response to a step-function input are shown in the figure. Typical components of a dc control system are potentiometers, dc amplifiers, dc motors, dc tachometers, and so on. Figure 1-13 shows the schematic diagram of a typical ac control system that performs essentially the same task as the dc system in Fig. 1-12. In this case, the signals in the system are modulated; that is, the information is transmitted by an ac carrier signal. Ac control systems are used extensively in aircraft and missile control systems in which noise and disturbance often create problems. By using modulated ac control systems with carrier frequencies of 400 Hz or higher, the system will be less susceptible to low-frequency noise. Typical components of an ac control system are synchros, ac amplifiers, ac motors and gyroscopes.

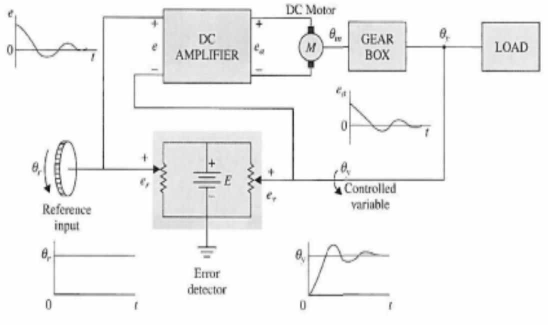


Figure 1-12 Schematic diagram of a typical dc closed-loop system.

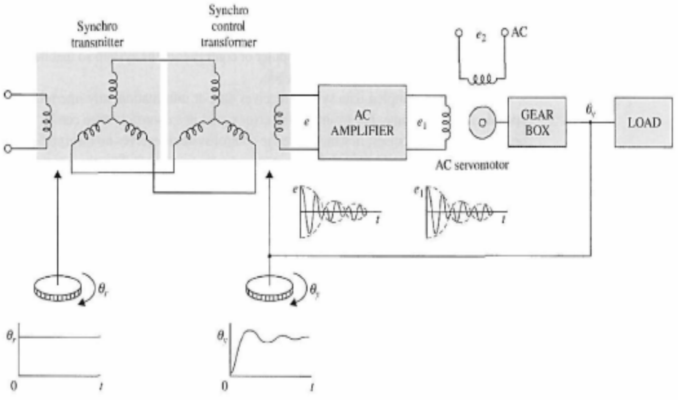


Figure 1-13 Schematic diagram of a typical ac closed-loop control system.

Discrete-Data Control Systems

In Discrete-data control the signals at one or more points of the system are in the form of either a pulse train or a digital code. Discrete-data control systems are subdivided into sampled- data and digital control systems. Sampled-data control systems refer to a more general class of discrete-data systems in which the signals are in the form of pulse data. A digital control system refers to the use of a digital computer or controller in the system so that the signals are digitally coded, such as in binary code. In general, a sampled-data system receives data or information only intermittently at specific instants of time. For example, the error signal in a control system can be supplied only in the form of pulses, in which case the control system receives no information about the error signal during the periods between two consecutive pulses. Strictly, a sampled-data system can also be classified as an ac system, because the signal of the system is pulse modulated. Figure 1-14 illustrates how a typical sampled-data system operates. A continuous-data input signal r{t.) is applied to the system. The error signal e{t) is sampled by a sampling device, the sampler, and the output of the sampler is a sequence of pulses. The sampling rate of the sampler may or may not be uniform. There are many advantages to incorporating sampling into a control system. One important advantage is that expensive equipment used in the system may be time-shared among several control channels. Another advantage is that pulse data are usually less susceptible to noise. Because digital computers provide many advantages in size and flexibility. Figure 1-15 shows the basic elements of a digital autopilot for guided missile control.

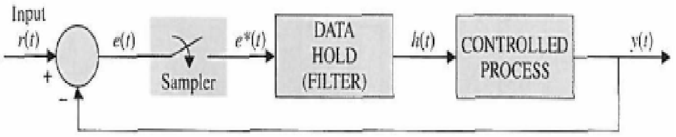


Figure 1-14 Block diagram of a sampled-data control system.

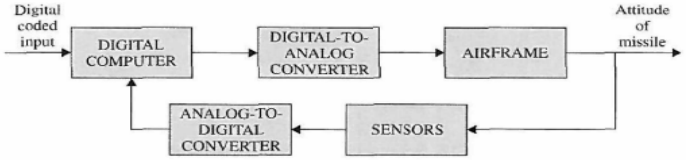


Figure 1-15 Digital autopilot system for a guided missile.

Title: < Time-Invariant versus Time-Varying Systems>

Description: < In this section we will discuss the Time-Invariant versus Time-Varying Systems>

Tags :< Time-Invariant-versus-Time-Varying-Systems>

Branch: <EEE>

Question:-

1. Explain Time-Invariant versus Time-Varying Systems?
2. Compare the Time-Invariant versus Time-Varying Systems?

Computer-Controlled Systems, Analysis and Design Objectives

Introduction

In this control system, system is controlled through computer and analysis and design objective also.

Computer-Controlled Systems, Analysis and Design Objectives

- In many modern systems, the controller (or compensator) is a digital computer.
- The advantage of using a computer is that many loops can be controlled or compensated by the same computer through time sharing.
- Furthermore, any adjustments of the compensator parameters required to yield a desired response can be made by changes in software rather than hardware.
- The computer can also perform supervisory functions, such as scheduling many required applications.
- For example, the space shuttle main engine (SSME) controller, which contains two digital computers, alone controls numerous engine functions.
- It monitors engine sensors that provide pressures, temperatures; flow rates, turbo pump speed, valve positions, and engine Servo valve actuator positions.
- The controller further provides closed-loop control of thrust and propellant mixture ratio, sensor excitation, valve actuators, spark igniters, as well as other functions.

Analysis and Design Objectives

- Analysis is the process by which a system's performance is determined.
- For example, we evaluate its transient response and steady-state error to determine if they meet the desired specifications.
- Design is the process by which a system's performance is created or changed.
- For example, if a system's transient response and steady-state error are analyzed and found not to meet the specifications, then we change parameters or add additional components to meet the specifications.
- A control system is dynamic: It responds to an input by undergoing a transient response before reaching a steady-state response that generally resembles the input.
- In this section, we discuss three major objectives of systems analysis and design: producing the desired transient response, reducing steady-state error, and achieving stability.
- We also address some other design concerns, such as cost and the sensitivity of system performance to changes in parameters.

Title: < Computer-Controlled Systems, Analysis and Design Objectives>

Description: < In this section we will discuss the Computer-Controlled Systems, Analysis and Design Objectives>

Tags :< Computer-Controlled Systems-Analysis-and-Design-Objectives>

Branch: <EEE>

Question:-

1. Explain computer controlled system?
2. Explain Analysis and design oblective?

Transient Response, Steady-State Response and Stability

Introduction

In this section we will discuss the Transient Response, Steady-State Response and Stability.

Transient Response, Steady-State Response and Stability

Transient Response

Transient response is important. In the case of an elevator, a slow transient response makes passengers impatient, whereas an excessively rapid response makes them uncomfortable. If the elevator oscillates about the arrival floor for more than a second, a disconcerting feeling can result. Transient response is also important for structural reasons: Too fast a transient response could cause permanent physical damage. In a computer, transient response contributes to the time required to read from or write to the computer's disk storage. Since reading and writing cannot take place until the head stops, the speed of the read/write head's movement from one track on the disk to another influences the overall speed of the computer. In this book, we establish quantitative definitions for transient response. We then analyze the system for its existing transient response. Finally, we adjust parameters or design components to yield a desired transient response our first analysis and design objective.

Steady-State Response

Another analysis and design goal focuses on the steady-state response. As we have seen, this response resembles the input and is usually what remains after the transients have decayed to zero. For example, this response may be an elevator stopped near the fourth floor or the head of a disk drive finally stopped at the correct track. We are concerned about the accuracy of the steady-state response. An elevator must be level enough with the floor for the passengers to exit, and a read/write head not positioned over the commanded track results in computer errors. An antenna tracking a satellite must keep the satellite well within its beam width in order not to lose track. In this text we define steady-state errors quantitatively, analyze a system's steady-state error, and then design corrective action to reduce the steady-state error our second analysis
And design objective.

Stability

Discussion of transient response and steady-state error is moot if the system does not have stability. In order to explain stability, we start from the fact that the total response of a system is the sum of the natural response and the forced response. When you studied linear differential equations, you probably referred to these responses as the homogeneous and the particular solutions, respectively. Natural response describes the way the system dissipates or acquires energy. The form or nature of this response is dependent only on the system, not the input. On the other hand, the form or nature of the forced response is dependent on the input. Thus, for a linear system, we can write

Total response = Natural response + Forced response (1.1)^2

For a control system to be useful, the natural response must eventually approach zero, thus leaving only the forced response, or oscillate. In some systems, however, the natural response grows without bound rather than diminish to zero or oscillate. Eventually, the natural response is so much greater than the forced response that the system is no longer controlled. This condition, called instability, could lead to self-destruction of the physical device if limit stops are not part of the design. For example, the elevator would crash through the floor or exit through the ceiling; an aircraft would go into an uncontrollable roll; or an antenna commanded to point to a target would rotate, line up with the target, but then begin to oscillate about the target with growing oscillations and increasing velocity until the motor or amplifiers reached Their output limits or until the antenna was damaged structurally. A time plot of an unstable system would show a transient response that grows without bound and without any evidence of a steady-state response. Control systems must be designed to be stable. That is, their natural response must decay to zero as time approaches infinity, or oscillate. In many systems the Transient response you see on a time response plot can be directly related to the natural response. Thus, if the natural response decays to zero as time approaches infinity, the transient response will also die out, leaving only the forced response. If the system is stable, the proper transient response and steady-state error characteristics can be designed. Stability is our third analysis and design objective.

Title: < Transient Response, Steady-State Response and Stability>

Description: < In this section we will discuss the Transient Response, Steady-State Response and Stability>

Tags :< Transient-Response-Steady-State-Response-and-Stability>

Branch: <EEE>

Question:-

1. Explain Transient Response?
2. Explain Steady-State Response?
3. Explain Stability?

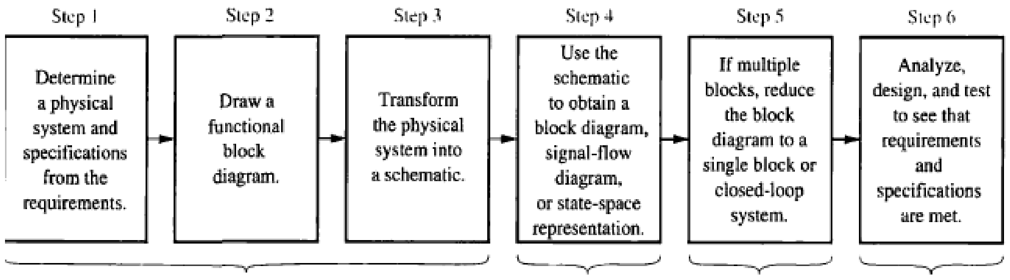
The Design Process, Part-1

Step 5: Reduce the Block Diagram

Subsystem models are interconnected to form block diagrams of larger systems, as in Figure 1.9(d), where each block has a mathematical description. Notice that many signals, such as proportional voltages and error, are internal to the system. There are also two signals—angular input and angular output—that are external to the system. In order to evaluate system response in this example, we need to reduce this large system's block diagram to a single block with a mathematical description that represents the system from its input to its output. Once the block diagram is reduced, we are ready to analyze and design the system.

Step 6: Analyze and Design

The next phase of the process, following block diagram reduction, is analysis and design. If you are interested only in the performance of an individual subsystem, you can skip the block diagram reduction and move immediately into analysis and Design. In this phase, the engineer analyzes the system to see if the response specifications and performance requirements can be met by simple adjustments of system parameters. If specifications cannot be met, the designer then designs additional hardware in order to affect a desired performance. Test input signals are used, both analytically and during testing, to verify the design. It is neither necessarily practical nor illuminating to choose complicated input signals to analyze a system's performance. Thus, the engineer usually selects standard test inputs. An impulse is infinite at t = 0 and zero elsewhere. The area under the unit impulse is 1. An approximation of this type of waveform is used to place initial energy into a system so that the response due to that initial energy is only the transient response of a system. From this response the designer can derive a mathematical model of the system. A step input represents a constant command, such as position, velocity, or acceleration. Typically, the step input command is of the same form as the output. For example, if the system's output is position, as it is for the antenna azimuth position control system, the step input represents a desired position, and the output represents the actual position. If the system's output is velocity, as is the spindle speed for a video disc player, the step input represents a constant desired speed, and the output represents the actual speed. The designer uses step inputs because both the transient response and the steady-state response are clearly visible and can be evaluated. The ramp input represents a linearly increasing command. For example, if the system's output is position, the input ramp represents a linearly increasing position, such as that found when tracking a satellite moving across the sky at constant speed. If the system's output is velocity, the input ramp represents a linearly increasing velocity. The response to an input ramp test signal yields additional information about the steady-state error. The previous discussion can be extended to parabolic inputs, which are also used to evaluate a system's steady-state error. Sinusoidal inputs can also be used to test a physical system to arrive at a mathematical model. We conclude that one of the basic analysis and design requirements is to evaluate the time response of a system for a given input. Throughout the book you will learn numerous methods for accomplishing this goal.The control systems engineer must take into consideration other characteristics about feedback control systems. For example, control system behavior is altered by fluctuations in component values or system parameters. These variations can be caused by temperature, pressure, or other environmental changes. Systems must be built so that expected fluctuations do not degrade performance beyond specified bounds. A sensitivity analysis can yield the percentage of change in a specification as a function of a change in a system parameter. One of the designer's goals, then, is to build a system with minimum sensitivity over an expected range of environmental changes. In this section we looked at some control systems analysis and design considerations. We saw that the designer is concerned about transient response, steady-state error, stability, and sensitivity. The text pointed out that although the basis of evaluating system performance is the differential equation, other methods, such as transfer functions and state space, will be used.



Title: < The Design Process>

Description: < In this section, we establish an orderly sequence for the design of feedback control systems that will be followed as we progress through the rest of the book. >

Tags :< The-Design-Process>

Branch: <EEE>

Question:-

1. Explain the design process?
2. What is the design process?

The Design Process

Introduction

In this section, we establish an orderly sequence for the design of feedback control systems that will be followed as we progress through the rest of the book.

The Design Process

In this process, the requirements have to be respecified and the design process repeated. Let us now elaborate on each block of Figure below.

Step 1: Transform Requirements into a Physical System

For example, in the antenna azimuth position control system, the requirements would state the desire to position the antenna from a remote location and describe such features as weight and physical dimensions. Using the requirements, design specifications, such as desired transient response and steady-state accuracy, are determined

Step 2: Draw a Functional Block Diagram

The designer now translates a qualitative description of the system into a functional block diagram that describes the component parts of the system (that is, function and/or hardware) and shows their interconnection. It indicates functions such as input transducer and controller, as well as possible hardware descriptions such as amplifiers and motors. At this point the designer may produce a detailed layout of the system, from which the next phase of the analysis and design sequence, developing a schematic diagram, can be launched.

Step 3: Create a Schematic

As we have seen, position control systems consist of electrical, mechanical, and electromechanical components. After producing the description of a physical system, the control systems engineer transforms the physical system into a schematic diagram. The control system designer can begin with the physical description, When we draw the potentiometers, we make our first simplifying assumption by neglecting their friction or inertia. These mechanical characteristics yield a dynamic, rather than an instantaneous, response in the output voltage. We assume that these mechanical effects are negligible and that the voltage across a potentiometer changes instantaneously as the potentiometer shaft turns. A differential amplifier and a power amplifier are used as the controller to yield gain and power amplification, respectively, to drive the motor. Again, we assume that the dynamics of the amplifiers are rapid compared to the response time of the motor; thus, we model them as a pure gain, K. A dc motor and equivalent load produce the output angular displacement. The speed of the motor is proportional to the voltage applied to the motor's armature circuit. Both inductance and resistance are part of the armature circuit. we assume the effect of the armature inductance is negligible for a dc motor. The designer makes further assumptions about the load. The load consists of a rotating mass and bearing friction. Thus, the model consists of inertia and viscous damping whose resistive torque increases with speed, as in an automobile's shock absorber or a screen door damper. The decisions made in developing the schematic stem from knowledge of the physical system, the physical laws governing the system's behavior, and practical experience. These decisions are not easy; however, as you acquire more design experience, you will gain the insight required for this difficult task.

Step 4: Develop a Mathematical Model (Block Diagram)

Once the schematic is drawn, the designer uses physical laws, such as Kirchhoff's laws for electrical networks and Newton's law for mechanical systems, along with simplifying assumptions, to model the system mathematically. These laws are Kirchhoff's voltage law The sum of voltages around a closed path equals zero. Kirchhoffs current law The sum of electric currents flowing from a node equals zero. Newton's laws The sum of forces on a body equals zero;3 the sum of moments on a body equals zero. Kirchhoffs and Newton's laws lead to mathematical models that describe the relationship between the input and output of dynamic systems.

$$\frac{d^m c(t)}{dt^n} + d_{n-1}\frac{d^{m-1}c(t)}{dt^{n-1}} + \cdots + d_0 c(t) = b_m \frac{d^m r(t)}{dt^m} + b_{m-1}\frac{d^{m-1} r(t)}{dt^{m-1}} + \cdots + b_0 r(t)$$

Many systems can be approximately described by this equation, which relates the output, c(t), to the input, r(t), by way of the system parameters, a, and b. We assume the reader is familiar with differential equations. These equations complicate the design process and reduce the designer's insight. Of course, all assumptions must be checked and all simplifications justified through analysis or testing. In addition to the differential equation, the transfer function is another way of mathematically modeling a system. The model is derived from the linear, time-invariant differential equation using what we call the Laplace transform. Although the transfer function can be used only for linear systems, it yields more intuitive information than the differential equation. We will be able to change system parameters and rapidly sense the effect of these changes on the system response. The transfer function is also useful in modeling the interconnection of subsystems by forming a block diagram similar to Figure 1.9(d) but with a mathematical function inside each block. Still another model is the state-space representation. One advantage of statespace methods is that they can also be used for systems that cannot be described by linear differential equations. Further, state-space methods are used to model systems for simulation on the digital computer Finally, we should mention that to produce the mathematical model for a system, we require knowledge of the parameter values, such as equivalent resistance, inductance, mass, and damping, which is often not easy to obtain. Analysis, measurements, or specifications from vendors are sources that the control systems engineer may use to obtain the parameters.

Computer Aided Design

Introduction

In this section we will discuss the computer aided design

Computer Aided Design

- We will discuss the use of the computer as a computational tool in this sequence. The computer plays an important role in the design of modern control systems. In the past, control system Design was labor intensive. Many of the tools we use today were implemented through hand calculations or, at best, using plastic graphical aid tools.
- The process was slow, and the results not always accurate. Large mainframe computers were then used to simulate the designs. Today we are fortunate to have computers and software that remove the drudgery from the task. At our own desktop computers, we can perform analysis, design, and simulation with one program.
- With the ability to simulate a design rapidly, we can easily make changes and immediately test a new design. We can play what-if games and try alternate solutions to see if they yield better results, such as reduced sensitivity to parameter changes. We can include nonlinearities and other effects and test our models for accuracy.

MATLAB

- The computer is an integral part of modern control system design, and many computational tools are available for your use. In this section we use MATLAB and the MATLAB Control System Toolbox, which expands MATLAB to include control system-specific commands.
- In addition, presented are several MATLAB enhancements that give added functionality to MATLAB and the Control Systems Toolbox.
- Included are (1) Simulink, which uses a graphical user interface (GUI); (2) the LTI Viewer, which permits measurements to be made directly from time and frequency response curves; (3) the SISO Design Tool, a convenient and intuitive analysis and design tool; and (4) the Symbolic Math Toolbox, which saves labor when making symbolic calculations required in control system analysis and design.
- Some of these enhancements may require additional software available from The Math Works, Inc. MATLAB is presented as an alternate method of solving control systemProblems. You are encouraged to solve problems first by hand and then by MATLAB so that insight is not lost through mechanized use of computer programs.
- Various icons appear in the margin to identify MATLAB references that direct you to the proper program in the proper appendix and tell you what you will learn.
- MATLAB code itself is not platform specific. The same code runs on PCs and workstations that support MATLAB.
- Although there are differences in installing and managing MATLAB files, we do not address them in this book. Also, there are many more commands in MATLAB and the MATLAB toolboxes than are covered in the appendixes.
- Lab VIEW is a programming environment presented as an alternative to MATLAB.
- This graphical alternative produces front panels of virtual instruments on your computer that are pictorial reproductions of hardware instruments, such as waveform generators or oscilloscopes.
- Underlying the front panels are block diagrams. The blocks contain underlying code for the controls and indicators on the front panel. Thus, a knowledge of coding is not required.
- Also, parameters can be easily passed or viewed from the front panel.
- A LabVIEW tutorial is in Appendix D and all LabVIEW material is identified with the LabVIEW icon shown in the margin. Now that we have introduced control systems to you and established a need for computational aids to perform analysis and design.

Title: < computer aided design >

Description: < In this section we will discuss the computer aided design >

Tags :< computer-aided-design >

Branch: <EEE>

Question:-

1. What is computer aided design?
2. Explain computer aided design?

The Control Systems Engineer

Introduction

In this section we will discuss the Control Systems Engineer.

The Control Systems Engineer

Control systems engineering is an exciting field in which to apply your engineering talents, because it cuts across numerous disciplines and numerous functions within those disciplines. The control engineer can be found at the top level of large projects, engaged at the conceptual phase in determining or implementing overall system requirements. These requirements include total system performance specifications, subsystem functions, and the interconnection of these functions, including interface requirements, hardware and software design, and test plans and procedures. Many engineers are engaged in only one area, such as circuit design or software development. However, as a control systems engineer, you may find yourself working in a broad arena and interacting with people from numerous branches of engineering and the sciences. For example, if you are working on a biological system, you will need to interact with colleagues in the biological sciences, mechanical engineering, electrical engineering, and computer engineering, not to mention mathematics and physics. You will be working with these engineers at all levels of project development from concept through design and, finally, testing. At the design level, the control systems engineer can be performing hardware selection, design, and interface, including total subsystem design to meet specified requirements. The control engineer can be working with sensors and motors as well as electronic, pneumatic, and hydraulic circuits. The space shuttle provides another example of the diversity required of the systems engineer. In the previous section, we showed that the space shuttle's control systems cut across many branches of science: orbital mechanics and propulsion, aerodynamics, electrical engineering, and mechanical engineering. Whether or not you work in the space program, as a control systems engineer you will apply broad based knowledge to the solution of engineering control problems. You start from the components, develop circuits, and then assemble a product. In top down design, a high-level picture of the requirements is first formulated; then the functions and hardware required to implement the system are determined. You will be able to take a top-down systems approach as a result of this course. A major reason for not teaching top-down design throughout the curriculum is the high level of mathematics initially required for the systems approach. For example, control systems theory, which requires differential equations, could not be taught as a lower-division course. However, while progressing through bottom-up design courses, it is difficult to see how such design fits logically into the large picture of the product development cycle. After completing this control systems course, you will be able to stand back and see how your previous studies fit into the large picture. Your amplifier course or vibrations course will take on new meaning as you begin to see the role design work plays as part of product development. For example, as engineers, we want to describe the physical world mathematically so that we can create systems that will benefit humanity. You will find that you have indeed acquired, through your previous courses, the ability to model physical systems mathematically, although at the time you might not have understood where in the product development cycle the modeling fits. This course will clarify the analysis and design procedures and show you how the knowledge you acquired fits into the total picture of system design. Understanding control systems enables students from all branches of engineering to speak a common language and develop an appreciation and working knowledge of the other branches. You will find that there really is not much difference among the branches of engineering as far as the goals and applications are concerned. As you study control systems, you will see this commonality. Control systems contribute to every aspect of modern society. In our homes we find them in everything from toasters to heating systems to VCRs. Control systems also have widespread applications in science and industry, from steering ships and planes to guiding missiles and the space shuttle. Control systems also exist naturally; our bodies contain numerous control systems. Even economic and psychological system representations have been proposed based on control system theory. Control systems are used where power gain, remote control, or conversion of the form of the input is required. A control system has an input, a process, and an output. Control systems can be open loop or closed loop. Open-loop systems do not monitor or correct the output for disturbances; however, they are simpler and less expensive than closed-loop systems. Closed-loop systems monitor the output and compare it to the input. If an error is detected, the system corrects the output and hence corrects the effects of disturbances. Control systems analysis and design focuses on three primary objectives:

1. Producing the desired transient response 2. Reducing steady-state errors 3. Achieving stability

A system must be stable in order to produce the proper transient and steady state response. Transient response is important because it affects the speed of the system and influences human patience and comfort, not to mention mechanical stress. Steady-state response determines the accuracy of the control system; it governs how closely the output matches the desired response. The design of a control system follows these steps:

Step 1 Determine a physical system and specifications from requirements.
Step 2 Draw a functional block diagram.
Step 3 Represent the physical system as a schematic.
Step 4 Use the schematic to obtain a mathematical model, such as a block diagram.
Step 5 Reduce the block diagram.
Step 6 Analyze and design the system to meet specified requirements and specifications
That include stability, transient response, and steady-state performance. In the next chapter we continue through the analysis and design sequence and learn how to use the schematic to obtain a mathematical model.

Title: < The Control Systems Engineer>

Description: < In this section we will discuss The Control Systems Engineer>

Tags :< The-Control-Systems-Engineer>

Branch: <EEE>

Question:-

1. Control system engineer, Explain?
2. What is The Control Systems Engineering?