VISVESVARAYA TECHNOLOGICAL UNIVERSITY

JNANA SANGAMA, BELGAVI -590 014

"Control Systems (22BEC403)"

IPCC

(Theory / Practical)

(Effective from the academic Year 2024-2025)

Study Material for CS

EVEN SEMESTER – IV

Subject Code: 22BEC403

(Choice Based Credit System)

Prepared by:

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Department of Electronics& Communication Engineering

Akshaya Institute of Technology

(Recognized by AICTE, New Delhi and Affiliated to Visvesvaraya Technological , University, Belagavi)

Akshaya Institute of Technology lingapura, Obalapura post, Koratagere Road,

Tumakuru-distric-572106, Karnataka State, INDIA.

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STUDENT'S NAME: ……………………………………………………………

USN: ……………………………………………………………………………

BRANCH: ………………………………………………………………………

SECTION: ………………………………… **YEAR:** ……………………………

AKSHAYA INSTITUTE OF TECHNOLOGY

Lingapura, Obalapura Post, Koratagere Road, Tumakuru - 572106

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VISION

To produce competent engineering professionals in the field of Electronics and Communication Engineering by imparting value based quality technical education to meet the societal needs and to develop socially responsible citizens.

MISSION

M1: To provide strong fundamentals and technical skills in the field of Electronics and Communication Engineering through effective teaching learning process.

M2: Enhancing employability of the students by providing skills in the fields of VLSI, Embedded systems, Signal processing, etc., through Centre of Excellence.

M3: Encourage the students to participate in co-curricular and extra-curricular activities that creates a spirit of social responsibility and leadership qualities.

Program Specific Outcomes (PSOs)

After Successful Completion of Electronics and Communication Engineering Program Students will be able to

1. Apply fundamental knowledge of core. Electronics and Communication Engineering in the analysis, design and development of Electronics Systems as well as to interpret and synthesize experimental data leading to valid conclusions.
2. Exhibit the skills gathered to analyze, design, develop software applications and hardware products in the field of embedded systems and allied areas.

Program Educational Objectives (PEOs)

PEO1: Graduates exhibit their innovative ideas and management skills to meet the day to day technical challenges.

PEO2: Graduates utilize their knowledge and skills for the development of optimal solutions to the problems in the field of Electronics and Communication Engineering..

PEO3: Graduates exhibit good interpersonal skills, leadership qualities and adapt themselves for life-long Learning

Control Systems			
Course Code	**BEC403**	CIE Marks	50
Teaching Hours/Week (L: T: P)	(3:0:2)	SEE Marks	50
Total Hours of Pedagogy	40 hours Theory + 12 Lab slots	Total Marks	100
Credits	04	Exam Hours	03

Course objectives: This course will enable students to:

1. Understand basics of control systems and design mathematical models using block diagram reduction, SFG, etc.
2. Understand Time domain and Frequency domain analysis.
3. Analyze the stability of a system from the transfer function
4. Familiarize with the State Space Model of the system.

Teaching-Learning Process (General Instructions)

These are sample Strategies, which teacher can use to accelerate the attainment of the various course outcomes.

- Lecture method (L) does not mean only traditional lecture method, but different type of teaching methods may be adopted to develop the outcomes.
- Show Video/animation films to explain the different concepts of Linear Algebra & Signal Processing.
- Encourage collaborative (Group) Learning in the class.
- Ask at least three HOTS (Higher order Thinking) questions in the class, which promotes critical thinking.
- Adopt Problem Based Learning (PBL), which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information rather than simply recall it.
- Topics will be introduced in a multiple representation.
- Show the different ways to solve the same problem and encourage the students to come up withtheir own creative ways to solve them.
- Discuss how every concept can be applied to the real world - and when that's possible, it helps improve the students' understanding.
- Adopt Flipped class technique by sharing the materials / Sample Videos prior to the class and havediscussions on the that topic in the succeeding classes.
- Give Programming Assignments.

Module-1

Introduction to Control Systems: Types of Control Systems, Effect of Feedback Systems, Differential equation of Physical Systems -Mechanical Systems, Electrical Systems, Analogous Systems. (Textbook 1: Chapter 1.1, 2.2)

Teaching-LearningProcess	Chalk and Talk, YouTube videos **RBT Level:** L1, L2, L3

Module-2	
Block diagrams and signal flow graphs: Transfer functions, Block diagram algebra and Signal Flow graphs. (Textbook 1: Chapter 2.4, 2.5, 2.6)	
Teaching-LearningProcess	Chalk and Talk, YouTube videos, Any software tool to implement block diagram reduction techniques and Signal Flow graphs **RBT Level:** L1, L2, L3
Module-3	
Time Response of feedback control systems: Standard test signals, Unit step response of First and Second order Systems. Time response specifications, Time response specifications of second order systems, steady state errors and error constants. Introduction to PI, PD and PID Controllers (excluding design). (Textbook 1: Chapter 5.3, 5.4, 5.5)	
Teaching-LearningProcess	Chalk and Talk, YouTube videos, Any software tool to show time response for various transfer functions and PI, PD and PID controllers. **RBT Level:** L1, L2, L3
Module-4	
Stability analysis: Concepts of stability, Necessary conditions for Stability, Routh stability criterion, Relative stability analysis: more on the Routh stability criterion. **Introduction to Root-Locus Techniques**, The root locus concepts, Construction of root loci. (Textbook 1: Chapter 6.1, 6.2, 6.4, 6.5, 7.1, 7.2, 7.3)	
Teaching-LearningProcess	Chalk and Talk, YouTube videos, Any software tool to plot Root locus for various transfer functions **RBT Level:** L1, L2, L3
Module-5	
Frequency domain analysis and stability: Correlation between time and frequency response, Bode Plots, Experimental determination of transfer function. (Textbook 1: Chapter 4: 8.1, 8.2, 8.4) Mathematical preliminaries, Nyquist Stability criterion, (Stability criteria related to polar plots are excluded) (Textbook 1: 9.2, 9.3) **State Variable Analysis:** Introduction to state variable analysis: Concepts of state, state variable and state models. State model for Linear continuous –Time systems, solution of state equations. (Textbook 1: 12.2, 12.3, 12.6)	
Teaching-LearningProcess	Chalk and Talk, YouTube videos, Any software tool to draw Bode plot for various transfer functions **RBT Level:** L1, L2, L3

Suggested Learning Resources:

Text Books

1. Control Systems Engineering, I J Nagrath, M. Gopal, New age international Publishers, Fifth edition.

Web links and Video Lectures (e-Resources):

- https://nptel.ac.in/courses/108106098

Activity Based Learning (Suggested Activities in Class)/ Practical Based learning

Programming Assignments / Mini Projects can be given to improve programming skills

List of Reference Books

1. . **"Modern Control Engineering" by Katsuhiko Ogata**
2. **"Automatic Control Systems" by Benjamin C. Kuo and Farid Golnaraghi**

List of URLs, Text Books, Notes, Multimedia Content, etc

Control Systems https://nptel.ac.in/courses/108104091

Course Outcomes: Students will be able to

CO1: Model and analyze dynamic systems using mathematical tools.	**L2**	
CO2: Design control systems to achieve stability and performance criteria.	**L2**	
CO3: Implement various types of controllers such as PID and state feedback.	**L3**	
CO4: Use MATLAB/Simulink for simulation and analysis of control systems.	**L3**	
CO5: Apply control system concepts to real-world engineering problems	**L3**	

Subject Code:	BEC403	**TITLE:** Control Systems						**Faculty Name:**				
List of Course Outcomes	**Program Outcomes**											Total
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	
CO-1	3	2	2	1	2	-	-	-	1	1	-	2	14
CO-2	3	2	1	2	2	-	-	-	1	-	-	3	14
CO-3	3	1	1	1	2	-	-	-	1	-	-	3	12
CO-4	2	1	1	1	2	-	-	-	1	1	-	2	11
CO-5	2	1	2	1	2	-	-	-	1	1	-	2	12
Total	13	8	7	6	10	-	-	-	5	3	-	12	**63**

Subject Code:	BEC403	**TITLE:** CS	
List of Course Outcomes	**Program Specific Outcomes**		
	PSO1	**PSO2**	**Total**
CO-1	2	1	**3**
CO-2	2	1	**3**
CO-3	3	2	**5**
CO-4	2	2	**4**
CO-5	2	1	**3**
Total	**11**	**6**	**18**

Note: 3 = Strong Contribution 2 = Average Contribution 1 = Weak Contribution **-** = No Contribute

MODULE -1

Introduction:

A control system is one which can control any quantity of interest in a machine, mechanism or other equipment in order to achieve the desired performance or output.(or) A control system is an interconnection of components connected or related in such a manner as to command, direct, or regulate itself or another system. For example consider, the driving system of an automobile. Speed of the automobile is a function of the position of its accelerator. The desired speed can be maintained (or a desired change in speed can be achieved) by controlling pressure on the accelerator pedal. This automobile driving system (accelerator, carburetor and engine-vehicle) constitutes a control system.

Control systems find numerous and widespread applications from every day to extraordinary in science, industry, and home. Here are a few examples:

(a) Home heating and air-conditioning systems controlled by a thermostat

(b) The cruise (speed) control of an automobile

(c) Manual control

 (i) Opening or closing of a window for regulating air temperature or air quality

 (ii) Activation of a light switch to regulate the illumination in a room

 (iii) Human controlling the speed of an automobile by regulating the gas supply to theengine

(d) Automatic traffic control (signal) system at roadway intersections

(e) Control system which automatically turns on a room lamp at night, and turns it off in Day light

The general block diagram of a control system is shown below..

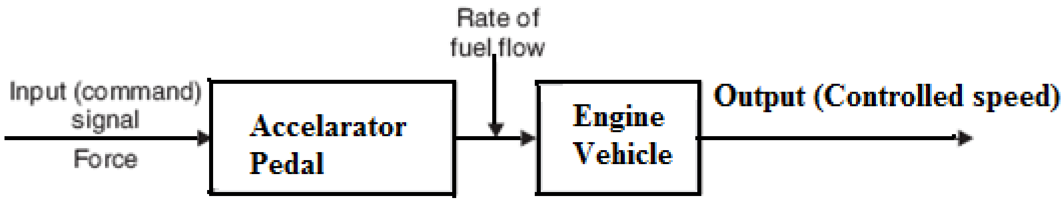

Fig.1.1. Block diagram of a control system.

The above method of representation of a control system is known as block diagram representation where in each block represents an element, a plant, mechanism, device etc., whose inner details are not indicated. Each block has an input and output signal which are linked by a relationship characterizing the block. It may be noted that the signal flow through the block is unidirectional.

Basic Control System components : The basic control system components are objectives i.e inputs or actuating signals to the system and the Output signals or controlled variables etc. The control system will control the outputs in accordance with the input signals. The relation between these components is shown in the block diagram.

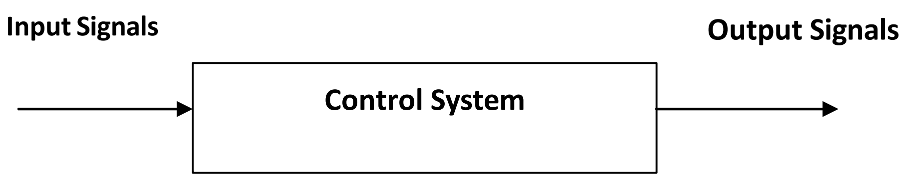

Fig.1.2 Block control system Components

The components of the control system changes as we move from open loop control system to closed loop control systems. In a closed loop control system, the feedback control network play an important role in getting the correct output.

The general block diagram of a control system with feedback is shown below. The error detector compares a signal obtained through feedback elements, which is a function of the output response, with the reference input. Any difference between these two signals gives an error or actuating signal, which actuates the control elements. The control elements in turn alter the conditions in the plant in such a manner as to reduce the original error.

Types of control systems:

There are basically two types of control systems (i) the open loop system and the (ii) closed loop System. They can both be represented by block diagrams. A block diagram uses blocks to represent processes, while arrows are used to connect different input, process and output parts.

(a) Open loop Control System : A system which do not possess any feedback network, and contains only the input and output relationship is known as a open loop control system.

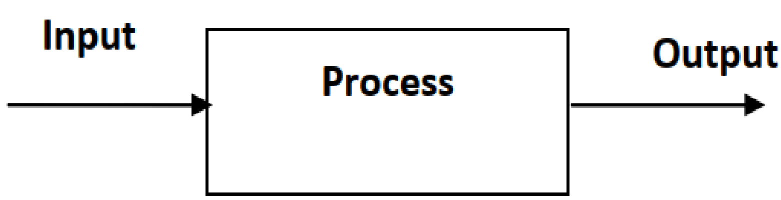

Fig.1.4. Open loop control system

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Examples of the open loop control systems are washing machines, light switches, gas ovens, burglar alarm system etc.The drawback of an open loop control system is that it is incapable of making automatic adjustments. Even when the magnitude of the output is too big or too small, the system can't make the necessary adjustments. For this reason, an open loop control system is not suitable for use as a complex control system.

(b) Closed loop control system: A closed loop system is one which uses a feed back control between input and output. A closed loop control system compares the output with the expected result or command status, and then it takes appropriate control actions to adjust the input signal. Therefore, a closed loop system is always equipped with a sensor, which is used to monitor the output and compare it with the expected result.

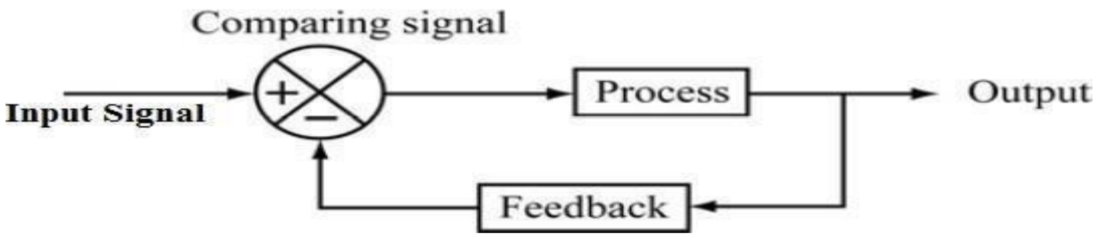

Fig.1.5.Closed Loop Control system

The output signal is fed back to the input to produce a new output. A well-designed feedback system can often increase the accuracy of the output.

Examples for closed loop systems are air conditioners, refrigerators, automatic rice cookers, automatic ticketing machines, etc. For example An air conditioner, uses a thermostat to detect the temperature and control the operation of its electrical parts to keep the room temperature at a preset constant.

One advantage of using the closed loop control system is that it is able to adjust its output automatically by feeding the output signal back to the input. When the load changes, the error signals generated by the system will adjust the output suitably. The limitation of a closed loop control systems is they are generally more complicated and thus also more expensive to design.

(c) Linear versus Nonlinear Control Systems : 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.

Also the analysis of linear systems is easy and lot of mathematical solutions is available for their simplification.

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. In practice , first a linear- system is modeled by neglecting the nonlinearities of the system and the designed controller is then applied to the nonlinear system model for evaluation or redesign by computer simulation.

Distinguish between Open loop and closed loop control systems

Open Loop System	Closed Loop System
1. An open loop system has the ability to perform accurately, if its calibration is good. If the calibration is not perfect its performance will go down.	1. A closed loop system has got the ability to perform accurately because of the feedback.
2. It is easier to build.	2. It is difficult to build.
3. In general it is more stable as the feed back is absent .	3. Less stable Comparatively
4. If-non-linearity's are present , the system operation is not good.	4. Even under the presence of non-linearity's the system operates better than open loop system.

d:Time-Invariant control Systems

When the parameters of a control system do not change with respect to time during the operation of the system, the system is called a time-invariant system. In practice, most physical systems contain elements that drift or vary with time. 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.

(d) Continuous and Discrete 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. In control systems the ac control system, 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 un-modulated, but they are still ac signals according to the conventional definition. The schematic diagram of a closed loop dc control system is shown below. 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.

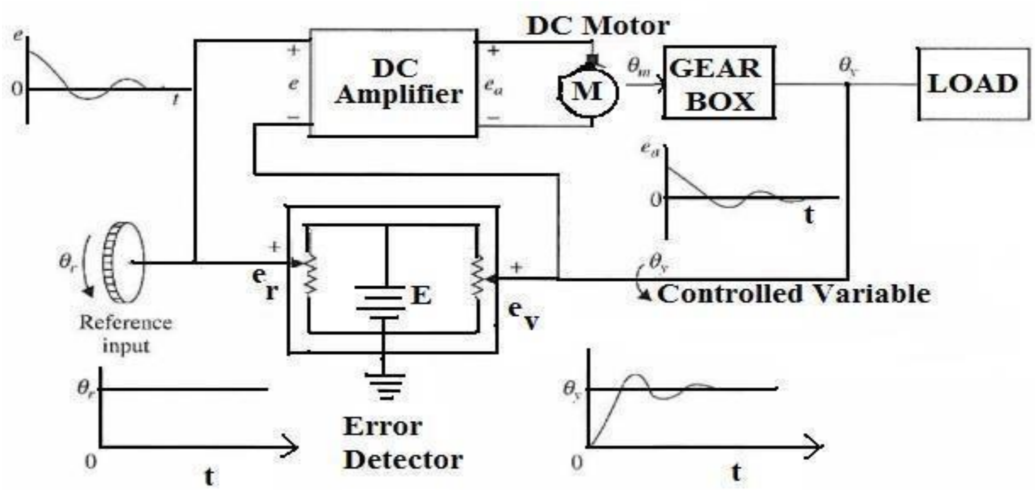

Fig 1.6 Block diagram of Continuous and Discrete Data Control Systems

In ac control systems, the signals are modulated i.e the information is transmitted by an ac carrier signal.

Here the output controlled variable behaves similarly to that ofthe dc system. In this case, the modulated signals are demodulated by the low-pass characteristics of the ac motor. 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, gyroscopes, accelerometers etc.

(e) Discrete Data Control System

If the signal is not continuously varying with time but it is in the form of pulses then the control system is called Discrete Data Control System. If the signal is in the form of pulse data, then the system is called Sampled Data Control System. Here the information supplied intermittently at specific instants of time. This has the advantage of Time sharing system. On the other hand, if the signal is in the form of digital code, the system is called Digital Coded System. Here use of Digital computers, micro processors or microcontrollers are made use of such systems and are analyzed by the Z- transform theory.

Applications of the control systems

There are various applications of control systems which include biological propulsion; locomotion; robotics; material handling; biomedical, surgical, and endoscopic ; aeronautics; marine and the defense and space industries. There are also many household and industrial application examples of the control systems, such as washing machine, air conditioner, security alarm system and automatic ticket selling machine, etc.

(i) Washing machine:

The most commonly used house hold application is the washing machine. It comes under automatic control system ,where the machine automatically starts to pour water, add washing powder, spin and wash clothes, discharge wastewater, etc. After the completion of all the procedures, the washing machine will stop the operation.

However, this kind of machine only operates according to the preset time to complete the whole washing process. It ignores the cleanness of the clothes and does not generate feedback. Therefore, this kind of washing machine is of open loop control system.

(ii). Air conditioner

The air conditioner is used to automatically control the temperature of the room.In the air conditioner the coolant circulated in the machine will absorb heat indoor, then it will be transported from the vaporization device to cooling device. The hot air is then blown to outdoor by a fan. There is an adjustable temperature device equipped in the air conditioner for the users to adjust the extent of cooling. When the temperature of the cool air is lower than the preset one, the controller of the air conditioner will stop the operation of the compressor to cease the circulation of the coolant. The temperature sensor installed near the vaporization device will continuously measure the indoor temperature, and send the results to the controller for further processing.This operation will come under closed loop control system. The simple block diagram of air conditioner system is shown below.

Feed back Control System

The feedback control system is represented by the following block diagram .In the diagram feedback signal is denoted by B(S) and the output is C(S).The input function is denoted by R(S).

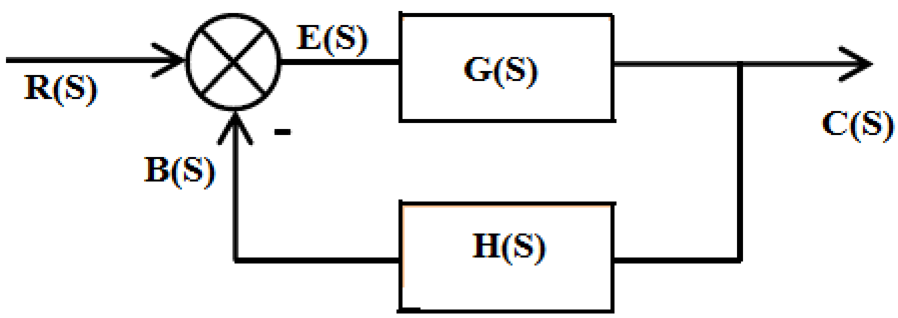

Fig .1.7 Feed Back Control System

The open loop gain of the system is G(S) and the feedback loop gain H(S). Then the feedback signal b(s) is given by

$$B(S) = H(S).\ C(S)$$