**Title of the course: Principles of Automotive Dynamics and Control**

1. Credit requirement: (L-T-P: 3-0-0, Credit: 3)

2. Please select the committee for Approval: PGPEC

3. Name of the Dept: ATDC

4. Please Specify the Level of the Subject: PG level

5. Whether the subject will be offered as compulsory or elective: Elective

6. Prerequisite(s) for the subject, if any
   (Please give the subject numbers and names): EE31009(CONTROL SYSTEM ENGINEERING), OR ME40601(SYSTEMS & CONTROL)OR AE21008 (INTRODUCTION TO FLIGHT VEHICLE CONTROLS)

**7. Course Objective**

Increasing interest, research and production of more advanced automotive systems is seen as a growing trend in the current scenario towards sustainable mobility. This is because, automotives play a crucial role in society for transportation, luxury and speed. A modern day vehicle is a combination of various electrical, electronic, mechanical and software components which successfully interact with each other to deliver the desired performance. Hence, due to the increased focus on automotive, a number of associated technologies are also getting advanced.

However, along with the advantages, a number of challenges arise such as pollution, safety, comfort, etc that have to be analyzed. Hence, the study of the dynamics of various components of vehicles and their interaction, their control and individual performance is crucial to understand the overall functioning which can lead to proposing an improved hardware/software/control structure as compared to the existing structure.

This course introduces the various components of a conventional modern automotive system and control loops after explaining the basic functioning, operation and architecture. Further, considering various factors affecting the performance and control actions in the components of a vehicle, models of the crucial elements of vehicle are developed and their interdependencies highlighted. For instance, there are models of engine, engine controller, electric components, transmission, vehicle dynamics and how they interact with each other so that control actions can be suitably taken. Also, the practical automotive sensors and actuators significantly participating in the control actions of a vehicle are studied. After understanding the requirement of control among various loops of the interacting components, fundamentals of control theory are reviewed to enable implementation of basic control to achieve the required functionality. This is followed by the introduction of Hybrid Electric Vehicle Systems as well as Autonomous vehicle and their basic control requirements. Case studies of basic control of vehicle dynamics, as well as EV and HEV are also provided to gain in-depth understanding of the nature of controls applied to complex automotive systems which will also give the students a realistic view of the subject as a whole.

In summary, students will learn in detail the various components (electrical, mechanical, electronics and software), their dynamics and interactions with each other as well as the architecture of an automobile and their governing principles of operation. They will also understand in detail the factors affecting the performance and control in vehicles after studying its crucial components. The control techniques taught will be useful to be applied to various significant components of an automobile. The students are expected to realize the advantages and challenges for automotive operation after analyzing the dynamics which will eventually enable them to design better control systems, taking the crucial requirements and constraints into consideration.

## 8. Study Materials

In this course, we will use textbooks only for building up the fundamental concepts. However, majority of the topics will be covered through lectures on important concepts available in the recently published articles, and presentation of the related papers and patents.

**Books:**


1. " Automotive Control Systems For Engine, Driveline, and Vehicle", by Uwe Kiencke and Lars Nielsen (Springer), 2000
2. "Electric and Hybrid Electric Vehicles: Technologies, Modeling and control: A Mechatronic Approach", by Amir Khajepour, Avesta Goodarzi and Saber Fallah(WILEY). 2014
3. " Fundamentals of Vehicle Dynamics", by Thomas D. Gillespie (SAE).1992
4. "Automotive Embedded Systems Handbook", by Nicolas Navet and Francoise Simonot-Lion (CRC). 2008
5. "Vehicle Dynamics", by N. Jazar (Springer), 2008,


## 9. Syllabus:

**1. Introduction to Automotive Systems [3L]**

Overall Architecture, operation, Overall process, Driving Cycles, Challenges. Brief overview of Powertrain Architecture, Embedded Systems Architecture, Communication Networks (CAN, LIN, Flexray, etc)

**2. Automotive Components and Their Models [6L]**

Powertrain Components, Transmission, Drives, Battery, Auxillary and their effects in dynamics

**3. Engine Basics and its control [6L]**

Types of IC engines, Construction, Operation, Dynamics, Control, OBD-II
**Engine controls -** Fuel Injection, λ Closed loop, EGR, Throttle, Knock.

**4. Vehicle Dynamics [5L]**

Kinematic Models, Motion Analysis, electronic Stability Control, Control of Semi active and active suspension

**5. Revision of Control Basics [3L]**

Closed Loop system, transfer functions, poles and zeros, bode plots, stability, Common control schemes like PID control and its application to vehicle dynamics

**6. Control loops in various ECUs (Overview) [2L]**

Engine Management System, Transmission Control Unit, Electric Power Assist System, Supervisory Control Unit, Battery Management Systems

**7. Automotive Sensors and Actuators [3L]**

Sensors and actuators for significant components, their characteristics and basic modeling

**8. Electric and Hybrid Vehicle System [4L]**

Basics of EV and HEV system, types, modeling and energy management based supervisory control.

**9. Introduction to Autonomous Vehicles [2L]**

Control requirements of AV, AV sensors and actuators, Case study: L1-L2 level of AV.

**10. Automotive standards [2L]**

Autosar, Functional Safety Standard (ISO 26262)

10. Names of the faculty members of the Department/Centers/School who have the necessary expertise and will be the willing to teach the subject (Minimum two faculty members should be willing to teach the subject)

**Somnath Sengupta (ATDC), Amit Patra (EE), Siddhartha Mukhopadhyay (EE) , and Alok Kanti Deb(EE)**

11. Do the contents of the subject have an overlap with any other subject offered in the Institute?

**Related Subjects offered by the Institute:**

ME60419 MODELING AND SIMULATION OF DYNAMIC SYSTEMS
ME60111 INTERNAL COMBUSTION ENGINE
ME60405 AUTOMATIC CONTROL
EE61011 AUTOMOTIVE SENSORS AND INSTRUMENTATION
ME41610 AUTOMOBILE ENGINEERING

a) Approximate percentage of overlap: (Overall) 10%

b) Reasons for offering the new subject in spite of the overlap:

The current focus of many industries across the globe is on the advancement and production of automotives. Understanding the dynamics and control requirements of Automotive systems are quite essential since they integrate various interdisciplinary domains into one system. Such a system is inherently complex because several components and their dynamics interact with each other in a well coordinated manner to result in one moving system. The control of Automotive is essential to ensure drivability, safety, improved performance and ensure the desired interaction with the environment.

Since, such knowledge is currently in high demand in numerous industries focused on automotive development and associated applications, thorough

understanding of the governing principles of various automotive dynamics and the ability to apply controls on some automotive systems would be useful for the students of our Institute. Additionally, the course would beof tremendous help for researcher scholars working in the area of electromechanical systems, embedded systems, control systems and of course systems associated with automotives. This proposed course primarily covers the basics of Automotive components and architecture, their individual and coordinated dynamics followed by their controls. Some advanced automotive systems and their controls are also discussed such as EV/HEV and Autonomous Vehicles for the benefit of students to get exposed to the transport of the future. The case studies provided are further expected to deepen their concepts. This course has *minimal* overlap with the subjects currently offered by the Institute.

**Related Subjects offered by the Institute**

**ME60419: MODELING AND SIMULATION OF DYNAMIC SYSTEMS**
**Syllabus: ( % Overlap: 5%)**

Elements of analytical mechanics; classification of constrains, Principles of virtual work, Lagrange;s first equation. Lagrange's second equation. Hamilton's equations. Nonholonomic mechanical system dynamics, Routh and Gibb's equation,Kane dynamics with application to multi body systems like mechanisms andmanipulators. Modelling of systems involving continuous medium. Hamilton's principle for continuous medium. Elements of thermo-continuum and theory of constitutive relations. Advanced topics in bond graph moedlling of physical systems : Elements of multi-bond graphs, Thermo-mechanical bond graphs and continuous systems and other systems of typical interest. Introduction to various system simulation software.

**Comment:** This course mostly focuses on the modeling and simulation to express mechanics of systems which may not necessarily be automotive. The mathematical techniques listed by this course will not be used by the proposed course. The proposed course is cross-domain in nature and combines several electromechanical, software and control components and their modeling as well. Syllabus wise, it has a minimal overlap with the proposed one.

**ME60111: INTERNAL COMBUSTION ENGINE**
**Syllabus: ( % Overlap: 5%)**

Air standard and fuel–air cycle analysis of Otto, Diesel and limited pressure cycles. Effect of design and operating parameters on cycle efficiency. Modified fuel-air cycle considering heat losses and valve timing. Engine dynamics and torque analysis. Fuels and combustion in S.I. engines, knocking and fuel rating. Energy balance, volumetric efficiency, measurement of indicated and brake power. Advanced theory of carburetion. Cooling of engine and governing of engine. Ignition system: conventional and electronic. Supercharging. Variable compression ratio engine. Wankel rotary combustion engine. Exhaust emissions, its measurement and control. Fault diagnosis of S.I. Engines. Modelling of I.C. Engine Combustion.

**Comment:** This course mostly focus on the concepts of engine cycle, the attributes and the different process occurring in the engine along with the variety of engines and modeling of combustion. Though the proposed course also describes engines and its dynamics, but the course also connects all the dynamical processes of the engine to the corresponding controls. So,

the proposed course aims at the different aspect of Engine and its interaction with the rest of the automotive system. Syllabus wise, it has a minimal overlap with the proposed one.

**ME60405: AUTOMATIC CONTROL**

**Syllabus: ( % Overlap: 5%)**

Introduction; Mathematical models of physical system; Feedback characteristics of control systems; Control systems and components; Time response analysis, design specifications and performance indices; Concepts of stability and algebraic criteria; Root locus technique; Frequency response analysis; Stability in frequency domain; Introduction to design; State variable analysis and design.

**Comment:** This course covers mathematical models of physical systems which may not be automotive systems as well as their basic control aspects, without considering a complete system comprising of several subsystems as a whole. Since the proposed course is dedicated to the dynamics and controls of Automotive systems which have components from different domains such as electrical, mechanical and software, the extent of overlap is expected to be minimal.

**EE61011 AUTOMOTIVE SENSORS AND INSTRUMENTATION**

**Syllabus: ( % Overlap: 5%)**

Angular & Linear Position Sensors and Interface Electronics, Automotive Speed and Torque Sensors, Accelerometers in Automotives, Pressure and Temperature Sensors for Automotives , Mass Airflow and Oxygen/Fuel Composition Sensors, Comfort, Convenience and Security Sensors, Occupant Safety Sensors, Automotive Sensors for the Future& Conclusion, Virtual Instrumentation for Automotive Research & Development

**Comment:** This course totally focuses on different kinds of automotive sensors. However, the proposed course being concerned with the control aspects covers automotive actuators as well. Further, the focus of automotive sensors and actuators is limited to a few lectures which show that this subject is a small fraction of the proposed course. Hence, this course has minimal overlap with the proposed one.

**ME41610 AUTOMOBILE ENGINEERING**

**Syllabus: ( % Overlap: 10%)**

Introduction to Automobiles, Basics of Otto and Diesel cycle, Elements of Petrol and Diesel Engine, Engine Performance curves, Vehicle Performance Characteristics and Requirements, Power-train, Transmission and Drive units, Exhaust System and Emissions, Steering and Suspension System, Chassis and Body Design, Brake systems, Electrical and Lighting Systems, Safety and Comfort Features, Wheel and Tyre, NVH Considerations in Vehicle Design, Vehicle Ride and Handling Evaluation, Basics of Automobile Manufacturing, Electric and Hybrid Vehicles.

**Comment:** This course mainly focuses on the fundamentals of the components of automobiles from a construction/architecture point of view. This does not include the electronic control units and their interactions with the major components of the automobile. The Scope/objective of the course is for design/construction of the automobile rather than the control framework. Though the proposed course also describes many of the automobile components mentioned in this course but perspective is mainly from the analysis of dynamics and control aspects of those components and hence the overlap is minimal.