Automotive Sensors and Instrumentation

LTP = 3-1-0, Lectures = 40, Practical Session (Tutorials) – 5 Hours, Evaluation =20 (Attendance, Assignments, Class tests) + 30 (Mid-term) + 50 (End-term)
Target: UG4, DD, PG, PhD
Prerequisite: NIL
Semester: Autumn
Faculty: Anoop C. S., Karabi Biswas, Alok Barua

1. **Introduction**(3 lectures)

Lecture 1

1.1. Automotive Sensors
Automotive Sensors – Evolution and Current Industry, General Requirements and Considerations for Automotive Sensors – Technical, Marketing, Environmental, etc

Lecture 2

1.2. Broad Classification and Conventional Sensors
Power train, Chassis and Body Sensors, Explanation about their main functions, sensors and electronics involved. Brief overview of common conventional sensing methods

Lecture 3

1.3. State-of-the-Art Sensing Techniques
Wiegand Effect,Giant Magnetoresistance (GMR), Tunneling Magnetoresistance (TMR) – Principle, Characteristics and Applications
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Assignment 1

Preparation of a List of Conventional Sensing Methods, along with their Characteristics and Major Automotive Applications

2. **Angular & Linear Position Sensors and Interface Electronics** (6 lectures)

Lecture 4

2.1. Need of Position Sensing in Automotives
Typical Measurands, Requirements and Challenges, Common Techniques and Issues

Lecture 5

2.2. Capacitive Full-turn Angle Transducer
Sensor Design, Signal Conditioning and Uses

Lecture 6

2.3. GMR Based Angle Transducer
Sensing Arrangement and Characteristics, Linearization Electronics – Methodology

Lecture 7

2.4. GMR Based Angle Transducer – Contd.
Circuit Design and Analysis

Lecture 8

2.5. Hall Effect Based Linear Position Sensor, Appropriate Technology for Different Applications

Lecture 9

2.6. Special Application: Brake Wear Monitoring
Existing Sensors and their Relative Merits, Combined Reluctance-Hall Effect Angle Transducer–Sensing Arrangement and Signal Conditioning

3. Automotive Speed and Torque Sensors (6 Lectures)

Lecture 10

3.1. Need of Speed Sensors, Typical Measurands, Sensing Principles Employed

Lecture 11

3.2. Application 1: Crankshaft Reverse Rotation Detection

Problem Definition, Typical Sensors and Electronics Employed

Lecture 12

3.3. Application 2: Wheel Speed and Direction Detection

Variable Reluctance Sensors, Magnetic Encoders, Self monitored Failure Detection Schemes

Lecture 13

3.4. Applications of Torque Sensors, Strain Gauge Torque Transducers

Lecture 14

3.5. Torsion Bars – Capacitive and Optical

Principle of Operation, Signal Conditioning Circuits and Performance Characteristics

Lecture 15

3.6. Surface Acoustic Wave Torque Sensor and Magnetoelastic Torque Sensors

4. Accelerometers in Automotives(3 Lectures)

Lecture 16

4.1. Accelerometer and Applications

Description about Sensing Principles Employed, Appropriate Technology for Different Applications

Lecture 17

4.2. Gyroscope and Applications

Sensing Principles, Appropriate Technology for Different Applications

Lecture 18

4.3. Application 1: Chassis Acceleration

Accelerometer Design, Signal Conditioning and Features

5. Pressure and Temperature Sensors for Automotives (5 lectures)

Lecture 19

5.1. Pressure Sensors and Applications, Typical Automotive Pressure Sensors – I (Piezoresistive and Capacitive Touch-Mode Micromachined)

Lecture 20

5.2. Typical Automotive Pressure Sensors – II (Capacitive Ceramic Module, Piezoresistive PolySilicon-on-steel), Technology suited for different applications

Lecture 21

5.3. Application 1: Tire Pressure Measurement

Sensors used and Signal Conditioning

Lecture 22

5.4. Temperature Sensors and Indirect Measurement Methods (direct methods already covered)

Applications and Requirements, Explanation about Liquid Crystal, Thermostat and Heat Flux Gauge Technologies

Lecture 23

5.5. Appropriate Technology for Different Applications, Case Study: Exhaust Gas Temperature Measurement

6. Mass Airflow and Oxygen/Fuel Composition Sensors (5 lectures)

Lecture 24

6.1. Mass Air Flow Rate Sensors – Importance, Speed/Density (Indirect) Measurement Method, Direct Measurements – Moving-Vane Airflow Sensors

Lecture 25

6.2. Hot-wire and Hot-film transducers, Ultrasonic Flow meter.

Lecture 26

6.3. Exhaust Fuel Composition Sensor
Importance and Requirements, Lambda ratio, Sensing mechanism for NOx, CO, HC and particulates

Lecture 27

6.4. Exhaust Gas Oxygen (EGO) Sensor
Sensing using Zirconium Electrolyte, Lambda Control and Lean Burn Control Principle

Lecture 28

6.5. New EGO sensors and sensors for cabin air quality/humidity

7. Comfort, Convenience and Security Sensors (5 lectures)

Lecture 29

7.1. Sensors and Electronic Systems for Seat Positioning, Electrical Mirrors

Lecture 30

7.2. Sensors and Electronic Systems for Central Locking System and Electrical Windows

Lecture 31

7.3. Sensors for Automatic Dimming Mirrors, Solar Radiation/Twilight Sensors

Lecture 32

7.4. Rain Sensor – Infrared, Capacitive and Resistive Based Schemes

Lecture 33

7.5. Fluid Level Sensors – Applications, Sensing and Electronics Techniques and Comparison

8. Occupant Safety Sensors (6 lectures)

Lecture 34

8.1. Instrumentation System for Occupancy Detection – Inductive& Capacitive Sensing

Lecture 35

8.2. Seat Weight, Seat Belt Tension and Seat Buckle Sensors for Air Bag Control Systems

Lecture 36

8.3. Sensing Techniques for Automotive Driver State Monitoring –ECG based systems – optimal sensor placement and signal conditioning

Lecture 37

8.4. PPG based automotive driver state monitor – Sensor, Signal Conditioning and Test Inferences, Overview about Similar Strain Gauge and Image Based systems.

Lecture 38

8.5. Sensing Schemes for Vehicle Collision Avoidance, Lane departure warning systems

Lecture 39

8.6. Parking Sensors and Blind Spot Monitors – Radar, Ultrasound, Electromagnetic

9. Automotive Sensors for the Future& Conclusion (1 lecture)

Lecture 40

9.1. Overview About Different New Sensing Requirements and Their Possible Solutions

10. Virtual Instrumentation for Automotive Research & Development(3Tutorialsfor 5 Hours)

Practical Session -1 (2 Hours)

10.1. Virtual Instrumentation (VI) and Data Acquisition Systems (DAS)
Introduction to VI, Programming Language – LABVIEW, Tools sets and function blocks, DAS Concepts, LABVIEW Programming Illustration using simple examples

Practical Session – 2 (1 Hour)

10.2. LABVIEW Programming Illustration examples to illustrate acquisition and generation of voltages using DAS modules and Interfacing

Practical Session –3 (2 Hours)

10.3. Interfacing Automotive-compatible ICs (e.g., AA002 from NVE Corp., NTCLE413E2103F102L from Vishay Semiconductors, SS49E from Honeywell Corp., etc.) with DAS and LABVIEW

Recommended Text Books/References Books

a) Theory (Text Books):

1. *Automotive Electrics-Automotive Electronics*, Robert Bosch GmbH Ed., Springer Vieweg, 5th Ed., 2007
2. *Automobile Electrical and Electronic Systems*, Tom Denton, Taylor and Francis group, London and New York, 4th Ed., 2012
3. *Automotive Sensory Systems*, Christopher O. Nwagboso, Springer Netherlands, 1993

b) References (Literature):

1. *Automotive Sensors*, John Turner Ed., Momentum Press, LLC, New Jersey, 1st Ed., 2009
2. *New Automotive Sensors - A Review*, William J. Fleming, IEEE Sensor Journal, Vol. 8, No. 11, November 2008
3. *Understanding Automotive Electronics: An Engineering Perspective*, William Ribbens, Butterworth-Heinemann (Elsevier), 7th Ed., 2012
4. *Magnetic Multilayers and Giant Magnetoresistance*, Hartmann, U. (Ed.), Springer, Berlin, 2000
5. *Capacitive Sensors: Design and Applications*, Baxter L. K., IEEE Press, New York, 1997
6. *Measurement Systems*, E. O. Doebelin, Tata McGraw Hill, New Delhi, 5th Ed., 2003
7. *Operational Amplifiers*, Clayton G., Winder S., Elsevier India, New Delhi, 5th Ed, 2013
8. *Virtual Instrumentation Using Labview*, Jovitha J., PHI, New Delhi, 2010