Batteries & Management System.

Course Objectives	• Acquire comprehensive knowledge of the performance characteristics of various Li-ion batteries. • Gain proficiency in design battery packs and perform essential calculations related to their configuration and performance. • Demonstrate the ability to create and analyze battery models or simulations. • Develop skills to accurately estimate the state-of-charge in battery packs. • Insights into different BMS architectures and their application in real-world scenarios.
Course Outcomes	• Explore different Li-ion Batteries performance. • Design a Battery Pack and make related calculations. • Demonstrate a Battery Model or Simulation. • Estimate State-of-Charges in a Battery Pack. • Approach different BMS architectures during real world usage

Course Duration: 45 Hours

Course Curriculum:

UNIT I: ADVANCED BATTERIES

Li-ion Batteries-different formats, chemistry, safe operating area, efficiency, aging. Characteristics SOC, DOD, SOH. Balancing-Passive Balancing Vs Active Balancing. Other Batteries-NCM and NCA Batteries. *NCR18650B* specifications.

UNIT II: BATTERY PACK

Battery Pack- design, sizing, calculations, flow chart, real and simulation Mode, Peak power definition, testing methods-relationships with Power, Temperature and ohmic Internal Resistance. Cloud based and Local Smart charging.

UNITIII: BATTERY MODELLING

Battery Modelling Methods-Equivalent Circuit Models, Electrochemical Model, Neural Network Model. ECM Comparisons- Rint model, Thevenin model, PNGV model. State space Models Introduction, Battery Modelling software/simulation frameworks

UNIT IV: BATTERY STATE ESTIMATION

SOC Estimation- Definition, importance, single cell Vs series batteries SOC. Estimation Methods Load voltage, Electromotive force, AC impedance, Ah counting, Neural networks, Neuro-fuzzy forecast method, Kalman filter. Estimation Algorithms.

UNIT V: BMS ARCHITECTURE AND REAL TIME COMPONENTS

Battery Management System- need, operation, classification. BMS ASIC-bq76PL536A-Q1 Battery Monitor IC- CC2662R-Q1 Wireless BMS MCU. Communication Modules- CAN Open-Flex RayCANedge1 package.ARBIN Battery Tester. BMS Development with Modeling software and Model Based Design.

Test Projects:

Use Cases:

Industry Use-Cases

1. **Design A battery management system Circuit for A Single Li- Ion battery cell with overvoltage and Reverse polarity protection.**

   LEARNING OUTCOME

   - Demonstrate a comprehensive understanding of EV AND HEV battery technology and its management.

   ASSESSMENT CRITERIA

   - Interpret the architecture of an Electric Vehicle
   - Analyze integration and interface
   - Identify components and functional blocks
   - Select correct communication protocols

   Task 1: Simulate The basic Electrical and Electronics Components in Autodesk Tinker cad Software (BJT And MOSFET Switching)

   Task 2: Simulate A Function Generator and CRO Using Autodesk Tinker cad

   Task 3: Simulate A Voltage Divider and Voltage Reference Using Autodesk Tinker cad

   Task 4: Hands-on with the Different Components used in BMS And Simulate It Using Autodesk Tinker cad

   Task 5: Design A BMS Circuit for a Single Li-ion Battery

2. **Design A battery management system circuit for 4S1P with over voltage and over current protection.**

   LEARNING OUTCOME

   - Implement efficient charging strategies and maintenance practices for EV and HEV batteries

   ASSESSMENT CRITERIA

   - Interpret regulatory compliances
   - Evaluate various protection systems
   - Evaluate protection mechanisms

Task 1: Simulate The basic Electrical and Electronics Components in Autodesk Tinker cad Software (BJT And MOSFET Switching)

Task 2: Simulate A Function Generator and CRO Using Autodesk Tinker cad

Task 3: Simulate A Voltage Divider and Voltage Reference Using Autodesk Tinker cad

Task 4: Hands-On the Building A Battery Pack and Simulate It Using Autodesk Tinker cad

Task 5: Design A battery management system Circuit for 4S1P with overvoltage and over current protection

3. **Design A Real-Time SOC Estimation Circuit for a Battery**

LEARNING OUTCOME

- Analyze battery data and apply diagnostic techniques for monitoring battery health.

ASSESSMENT CRITERIA

- Use diagnostic tools for assessing battery health
- Develop maintenance predictive strategies
- Perform health analysis of a battery

Task 1: Simulate The basic Electrical and Electronics Components in Autodesk Tinker cad Software (BJT And MOSFET Switching)

Task 2: Simulate A Function Generator and CRO Using Autodesk Tinker cad

Task 3: Simulate A Battery and Measure Using a mega Microcontroller using Autodesk Tinker cad

Task 4: Hands-On Programming in ATMEGA Microcontroller and Simulate it using Autodesk Tinker cad

Task 5: Design a Microcontroller Based SOC Estimation Circuit

4. **Design A Real-Time Prediction Circuit for Battery Operation**

LEARNING OUTCOME

- Optimize EV AND HEV battery performance and lifespan through effective management techniques.

ASSESSMENT CRITERIA

- Evaluate various strategies to assess battery life
- Use software in optimizing EV AND HEV battery performance

Task 1: Simulate The basic Electrical and Electronics Components in Autodesk Tinker CAD Software (BJT And MOSFET Switching)

Task 2: Simulate A Function Generator and CRO Using Autodesk Tinker cad

Task 3: Simulate A Battery Pack and Measure Using ATMEGA Microcontroller using Autodesk Tinker cad

Task 4: Hands-On Programming in ATMEGA Microcontroller and Simulate it Using Autodesk Tinker cad

5. **Design A Real-Time Battery Testing and Monitoring System (Single Cell).**

LEARNING OUTCOME

- Optimize EV battery performance and lifespan through effective management techniques.

ASSESSMENT CRITERIA

- Evaluate various strategies to assess battery life
- Use software in optimizing EV AND HEV battery performance

Task 1: Simulate The basic Electrical and Electronics Components in Autodesk Tinker cad Software (BJT And MOSFET Switching)

Task 2: Simulate A Function Generator and CRO Using Autodesk Tinker cad

Task 3: Simulate A Battery and Voltage Reference Using Autodesk Tinker cad

Task 4: Hands-On Programming in ATMEGA Microcontroller and Simulate it Using Autodesk Tinker cad

Task 5: Design An ATMEGA Microcontroller Battery Testing Circuit

6. **Design A Real-Time Battery Testing and Monitoring System (Battery Pack)**

LEARNING OUTCOME

- Identify and discuss emerging trends and sustainable practices in EV AND HEV battery technology.

ASSESSMENT CRITERIA

- Identify techniques to integrate IoT techniques
- Utilizing ARM Microcontrollers for Battery Management
- Provide solutions for IoT integration

Task 1: Simulate The basic Electrical and Electronics Components in Autodesk Tinker cad Software (BJT And MOSFET Switching)

Task 2: Simulate A Function Generator and CRO Using Autodesk Tinker cad

Task 3: Simulate A Battery and Voltage Reference Using Autodesk Tinker cad

Task 4: Hands-On Programming in ATMEGA Microcontroller and Simulate it Using Autodesk Tinker cad

Task 5: Design An ATMEGA Microcontroller Battery Testing Circuit.

7. **Evolution and Technological Advancements of EV and HEV Batteries**

LEARNING OUTCOME

- Demonstrate a comprehensive understanding of the evolution and types of batteries used in EVs and HEVs.

ASSESSMENT CRITERIA

- Produce a detailed timeline of major advancements in battery technology.
- Compare and contrast at least three types of EV and HEV batteries.
- Deliver a presentation highlighting the importance of battery technology in modern vehicles.
- Analyze future trends and potential advancements in battery technology.

Task 1: Research the evolution of EV and HEV batteries over the past decade.

Task 2: Create a timeline showcasing major advancements in battery technology.

Task 3: Compare and contrast different types of batteries used in EVs and HEVs.

Task 4: Prepare a presentation on the importance of battery technology in modern vehicles.

Task 5: Discuss the future potential of battery technology in EVs and HEVs.

8. **Comprehensive Design and Architectural Framework of Battery Management Systems**

LEARNING OUTCOME

- Design and explain the architecture of a Battery Management System (BMS) and its components.

ASSESSMENT CRITERIA:

- Create a detailed sketch of a BMS architecture.
- Identify and describe the function of each component within the BMS.
- Develop a comprehensive flowchart illustrating the interaction between BMS components.
- Simulate and explain the data flow within the BMS using a software tool.

Task 1: Sketch a basic architecture of a Battery Management System (BMS).

Task 2: Identify and label the main components and functional blocks in the BMS.

Task 3: Explain the role of each component in the BMS.

Task 4: Create a flowchart showing how these components interact with each other.

Task 5: Simulate the data flow within the BMS using a software tool.

9. **System Integration and Communication Interfaces in Battery Management Systems**

LEARNING OUTCOME

- Demonstrate the ability to integrate a battery with a BMS and utilize appropriate communication protocols**.**

ASSESSMENT CRITERIA

- Document the steps involved in connecting a battery pack to a BMS.
- Explain the importance of various communication protocols used in BMS.
- Create and explain a wiring diagram for battery and BMS integration.
- Identify and solve potential integration challenges.
- Test and report on the functionality of the integrated system.

Task 1: Connect a battery pack to a BMS and document the steps.

Task 2: Identify the communication protocols used (e.g., CAN, SPI) and explain their importance.

Task 3: Design a wiring diagram for integrating a battery with the BMS.

Task 4: Analyze the potential challenges in system integration.

Task 5: Test the connectivity and functionality of the integrated system.

10. Safety Protocols and Regulatory Compliance for Electric Vehicle Batteries

LEARNING OUTCOME

- Analyze and implement safety measures and regulatory compliance in EV and HEV batteries.

ASSESSMENT CRITERIA

- List and explain common safety risks associated with EV and HEV batteries.
- Conduct and document a hazard analysis for a given battery system.
- Propose and implement risk mitigation strategies.
- Research and summarize regulatory compliance requirements.
- Implement and evaluate a protection mechanism in a simulated environment.

Task 1: List the common safety risks associated with EV and HEV batteries.

Task 2: Conduct a hazard analysis for a given battery system.

Task 3: Propose risk mitigation strategies for identified hazards.

Task 4: Research regulatory compliance requirements for battery safety.

Task 5: Implement a protection mechanism in a simulated environment.

11. Advanced Protection Mechanisms for Ensuring Battery Safety in EVs and HEVs

LEARNING OUTCOME

- Design and test protection mechanisms for EV and HEV batteries.

ASSESSMENT CRITERIA

- Design and document an overvoltage protection circuit.
- Implement and test reverse polarity protection.
- Develop a thermal management plan for a battery pack.
- Test and evaluate over-current protection mechanisms.
- Design and test a cooling system for heat dissipation in EV batteries.

Task 1: Design an overvoltage protection circuit for a battery system.

Task 2: Implement reverse polarity protection in a simulated environment.

Task 3: Create a thermal management plan for an EV battery pack.

Task 4: Test the effectiveness of over-current protection mechanisms.

Task 5: Develop a cooling system for heat dissipation in EV batteries.

12. Diagnostic Tools and Techniques for Effective Battery Health Monitoring

LEARNING OUTCOME

- Implement and utilize diagnostic tools for battery health monitoring.

ASSESSMENT CRITERIA

- Install and configure sensors for monitoring battery parameters.
- Use diagnostic tools to assess and document the health of a battery pack.
- Interpret diagnostic data to identify and explain potential issues.
- Develop and justify a predictive maintenance strategy based on

diagnostics.

- Implement and test fault detection and isolation techniques

Task 1: Install sensors for monitoring battery parameters (e.g., temperature, voltage).

Task 2: Use diagnostic tools to assess the health of a battery pack.

Task 3: Interpret the diagnostic data to identify potential issues.

Task 4: Develop a predictive maintenance strategy based on the diagnostics.

Task 5: Implement fault detection and isolation techniques.

13. Accurate Estimation Methods for Determining Battery State of Charge (SOC)

LEARNING OUTCOME

- Apply and evaluate different methods for estimating the State of Charge (SOC) of a battery.

ASSESSMENT CRITERIA

- Research and summarize various SOC estimation methods.
- Compare and evaluate the accuracy of different SOC estimation algorithms.
- Implement a SOC estimation algorithm in a software tool.
- Analyze and document the challenges in improving SOC estimation accuracy.
- Test and report on the SOC estimation method using a sample battery pack.

Task 1: Research various methods for estimating the SOC of a battery.

Task 2: Compare the accuracy of different SOC estimation algorithms.

Task 3: Implement a SOC estimation algorithm in a software tool.

Task 4: Analyze the challenges in improving SOC estimation accuracy.

Task 5: Test the SOC estimation method on a sample battery pack.

14. **Predictive Models and Techniques for Battery State of Health (SOH) Estimation**

LEARNING OUTCOME

- Develop and apply predictive models for estimating the State of Health (SOH) of a battery.

ASSESSMENT CRITERIA

- Define and explain parameters influencing SOH.
- Develop a predictive model for SOH estimation.
- Implement the SOH prediction model in a simulation tool.
- Conduct and document a long-term health assessment using the model.
- Propose and justify improvements to enhance SOH prediction accuracy.

Task 1: Define the parameters that influence the SOH of a battery.

Task 2: Develop a predictive model for SOH estimation.

Task 3: Implement the SOH prediction model in a simulation tool.

Task 4: Analyze the long-term health assessment of a battery using the model.

Task 5: Propose improvements to enhance the accuracy of SOH predictions.

15. Implementing Passive and Active Cell Balancing Techniques in Battery Packs

LEARNING OUTCOME

- Understand and implement various cell balancing techniques for battery packs.

ASSESSMENT CRITERIA

- Identify and explain causes of cell imbalance.
- Design and document a passive balancing circuit.
- Implement and test an active capacitive balancing circuit.
- Develop and test an active inductive balancing circuit.
- Compare and analyze the efficiency of different cell balancing techniques.

Task 1: Identify the causes of imbalance in battery cells.

Task 2: Design a passive balancing circuit for a battery pack.

Task 3: Implement an active capacitive balancing circuit.

Task 4: Develop an active inductive balancing circuit using a DC-DC converter.

Task 5: Compare the efficiency of different cell balancing techniques.

16. Strategies for Enhancing Battery Lifespan and Performance in EVs and HEVs

LEARNING OUTCOME

- Apply strategies to enhance the lifespan and performance of EV and HEV batteries.

ASSESSMENT CRITERIA

- Research and summarize strategies for extending battery lifespan.
- Implement and evaluate a temperature management plan.
- Develop and apply a balancing technique to maintain cell health.
- Create and test a software tool to optimize battery performance.
- Analyze and report on the impact of management techniques on battery lifespan.

Task 1: Research strategies for extending the lifespan of EV batteries.

Task 2: Implement a temperature management plan for a battery pack.

Task 3: Develop a balancing technique to maintain cell health.

Task 4: Create a software tool to optimize battery performance.

Task 5: Test the impact of different management techniques on battery lifespan.

17. Integrating Internet of Things (IoT) for Advanced Battery Management and Monitoring

LEARNING OUTCOME

- Implement IoT solutions for enhanced battery management and monitoring.

ASSESSMENT CRITERIA

- Design and document an IoT-enabled battery monitoring system.
- Implement remote monitoring capabilities using IoT devices.
- Set up and test a network for data acquisition.
- Utilize ARM microcontrollers for managing battery data.
- Analyze and report the benefits of IoT integration in battery management.

Task 1: Design an IoT-enabled battery monitoring system.

Task 2: Implement remote monitoring capabilities using IoT devices.

Task 3: Set up a network for data acquisition from the battery system.

Task 4: Use ARM microcontrollers to manage and process battery data.

Task 5: Analyse the benefits of IoT integration for battery management.

18. Simulation and Performance Analysis of Battery Packs Under Various Conditions

LEARNING OUTCOME

- Simulate and analyze the performance of battery packs under various conditions.

ASSESSMENT CRITERIA

- Write and explain equations for vehicle dynamics involving battery packs.
- Calculate and document the range of an EV using a given battery pack.
- Simulate constant power and voltage scenarios.
- Create and analyze a model to simulate a battery pack.
- Report on the performance improvements based on simulation results.

Task 1: Write equations for vehicle dynamics involving battery packs.

Task 2: Calculate the range of an EV using a specific battery pack.

Task 3: Simulate constant power and voltage scenarios for the battery pack.

Task 4: Create a model to simulate the battery pack's performance.

Task 5: Analyze and report on the performance improvements based on the simulation.

19. Sustainable Practices and Innovations in Battery Design and Management

LEARNING OUTCOME

- Identify and implement sustainable practices in battery design and management.

ASSESSMENT CRITERIA

- Research and propose eco-friendly battery design options.
- Develop and document energy-efficient manufacturing processes.
- Create a plan for recycling and end-of-life management.
- Design and evaluate a smart charging infrastructure.
- Develop and present a consumer awareness campaign on sustainable practices.

Task 1: Research eco-friendly battery design options.

Task 2: Develop energy-efficient manufacturing processes for batteries.

Task 3: Create a plan for recycling and end-of-life management of batteries.

Task 4: Design a smart charging infrastructure for EV batteries.

Task 5: Present a consumer awareness campaign on sustainable battery practices.

20. Emerging Trends and Future Prospects in Battery Management Technologies

LEARNING OUTCOME

- Analyze and discuss emerging trends and future prospects in battery management systems.

ASSESSMENT CRITERIA

- Identify and explain recent advancements in battery management systems.
- Research and document the latest trends in EV and HEV battery technology.

- Analyze and present case studies of innovative battery management solutions.
- Discuss and propose solutions to potential integration challenges.
- Predict and justify future prospects in battery management technology.

Task 1: Identify recent advancements in battery management systems.

Task 2: Research the latest trends in EV and HEV battery technology.

Task 3: Analyze case studies of innovative battery management solutions.

Task 4: Discuss potential integration challenges and propose solutions.

Task 5: Predict future prospects in battery management technology.

21. Evaluating and Implementing Communication Protocols in Battery Management Systems

LEARNING OUTCOME

- Implement and evaluate communication protocols in battery management systems.

ASSESSMENT CRITERIA

- Research and summarize common communication protocols used in BMS.
- Implement a CAN communication interface for a BMS.
- Design and test a SPI-based communication system.
- Evaluate the reliability and speed of different communication protocols.
- Develop and present a protocol selection guide for various BMS applications.

Task 1: Research common communication protocols used in BMS.

Task 2: Implement a CAN communication interface in a BMS.

Task 3: Design a SPI-based communication system for a BMS.

Task 4: Test the reliability and speed of different communication protocols.

Task 5: Develop a protocol selection guide for BMS applications.

22. Utilizing Diagnostic Tools for Comprehensive Battery Health Assessment

LEARNING OUTCOME

- Utilize diagnostic tools to assess and improve battery health.

ASSESSMENT CRITERIA

- List and explain the features of various diagnostic tools.
- Conduct a comparative analysis of different diagnostic tools.
- Implement a diagnostic tool in a battery management system.
- Develop and apply a methodology for interpreting diagnostic data.
- Propose and justify improvements to enhance diagnostic tool accuracy.

Task 1: List the features of various diagnostic tools for battery health.

Task 2: Compare different diagnostic tools based on their features.

Task 3: Implement a diagnostic tool in a BMS.

Task 4: Develop a methodology for interpreting diagnostic data.

Task 5: Propose improvements to enhance the accuracy of diagnostic tools.

23. Developing Predictive Maintenance Strategies for Electric Vehicle Batteries

LEARNING OUTCOME

- Develop and implement predictive maintenance strategies for EV and HEV batteries.

ASSESSMENT CRITERIA

- Define key performance indicators for battery health monitoring.
- Develop a predictive maintenance model for EV batteries.
- Implement the model in a simulation tool.
- Test and document the model's performance on a sample battery pack.
- Create and justify a maintenance schedule based on predictive analysis.

Task 1: Define key performance indicators for battery health monitoring.

Task 2: Develop a predictive maintenance model for EV batteries.

Task 3: Implement the predictive maintenance model in a simulation tool.

Task 4: Test the model's performance on a sample battery pack.

Task 5: Create a maintenance schedule based on predictive analysis.

24. Temperature Sensing and Control Mechanisms for Optimal Battery Performance

LEARNING OUTCOME

- Implement and evaluate temperature sensing and control mechanisms for batteries.

ASSESSMENT CRITERIA

- Research and summarize different temperature sensing techniques.
- Implement a temperature sensing system in a battery pack.
- Develop and test a control algorithm for maintaining optimal battery temperature.
- Evaluate the effectiveness of the temperature control system.
- Propose and justify improvements to enhance thermal management.

Task 1: Research different temperature sensing techniques for batteries.

Task 2: Implement a temperature sensing system in a battery pack.

Task 3: Develop a control algorithm for maintaining optimal battery temperature.

Task 4: Test the effectiveness of the temperature control system.

Task 5: Propose improvements for better thermal management in battery systems.

25. Fault Detection and Isolation Techniques in Battery Management Systems

LEARNING OUTCOME

- Develop and apply fault detection and isolation techniques in battery management.

ASSESSMENT CRITERIA

- Identify and explain common faults in EV and HEV batteries.

- Develop a fault detection algorithm for a battery management system.
- Implement and test the fault detection algorithm in a simulation tool.
- Analyze and report on the algorithm's performance.
- Propose and justify strategies for effective fault isolation and recovery.

Task 1: Identify common faults in EV and HEV batteries.

Task 2: Develop a fault detection algorithm for a BMS.

Task 3: Implement the fault detection algorithm in a simulation tool.

Task 4: Test and analyze the performance of the fault detection algorithm.

Task 5: Propose strategies for fault isolation and recovery in battery systems.

26. **Designing and Implementing Smart Charging Infrastructure for EV Batteries**

LEARNING OUTCOME

- Design and implement smart charging infrastructure for EV and HEV batteries.

ASSESSMENT CRITERIA

- Research and summarize smart charging technologies.
- Design and document a smart charging station.
- Implement and evaluate a smart charging algorithm.
- Analyze the impact of smart charging on battery lifespan and performance.
- Develop and test a user interface for the smart charging station.

Task 1: Research smart charging technologies for EV and HEV batteries.

Task 2: Design a smart charging station for EV batteries.

Task 3: Implement a smart charging algorithm.

Task 4: Analyze the impact of smart charging on battery lifespan and performance.

Task 5: Develop a user interface for the smart charging station