Universitatea Națională de Știință și Tehnologie Politehnica București
Facultatea de Electronică, Telecomunicații și
Tehnologia Informației

COURSE DESCRIPTION

1. Program identification information

1.1 Higher education institution	**National University of Science and Technology Politehnica Bucharest**
1.2 Faculty	**Electronics, Telecommunications and Information Technology**
1.3 Department	**Telecommunications**
1.4 Domain of studies	Electronic Engineering, Telecommunications and Information Technology
1.5 Cycle of studies	Masters
1.6 Programme of studies	Electric Vehicle Propulsion and Control

2. Date despre disciplină

2.1 Course name (ro) (en)			Sisteme de management al bateriilor și ciclul de viață al bateriilor Battery Management Systems and Battery Life Cycle				
2.2 Course Lecturer			Conf. Dr. Lucian Andrei PERIȘOARĂ				
2.3 Instructor for practical activities			Conf. Dr. Lucian Andrei PERIȘOARĂ				
2.4 Year of studies	2	2.5 Semester	I	2.6. Evaluation type	E	2.7 Course regime	Ob
2.8 Course type		DA	2.9 Course code	UPB.04.M3.O.24-23		2.10 Tipul de notare	Nota

3. Total estimated time (hours per semester for academic activities)

3.1 Number of hours per week	3	Out of which: 3.2 course	2.00	3.3 seminary/laboratory	1
3.4 Total hours in the curricula	42.00	Out of which: 3.5 course	28	3.6 seminary/laboratory	14
Distribution of time:					hours
Study according to the manual, course support, bibliography and hand notes Supplemental documentation (library, electronic access resources, in the field, etc) Preparation for practical activities, homework, essays, portfolios, etc.					56
Tutoring					0
Examinations					2
Other activities (if any):					0

3.7 Total hours of individual study	58.00
3.8 Total hours per semester	100
3.9 Number of ECTS credit points	4

4. Prerequisites (if applicable) (where applicable)

4.1 Curriculum	Electronic Devices, Electronic Circuits, Digital Integrated Circuits, Microcontrollers, Electronics and Industrial Informatics, Power Electronics, Fundamentals of Electric Vehicles
4.2 Results of learning	General knowledge of electrical and electronic circuits, measurement techniques, power converters

5. Necessary conditions for the optimal development of teaching activities (where applicable)

5.1 Course	The lectures will be taken in a classroom with video projector and computer.
5.2 Seminary/ Laboratory/Project	Practical activities will be taken in a specialized laboratory, which will contain: testing platform for electric vehicles, testing platforms for battery management systems, electronic control units for vehicles, charging stations for electric vehicles, dedicated test and measurement equipments.

6. General objective *(Reffering to the teachers' intentions for students and to what the students will be thought during the course. It offers an idea on the position of course in the scientific domain, as well as the role it has for the study programme. The course topics, the justification of including the course in the currcula of the study programme, etc. will be described in a general manner)*

Vehicle electrification is now commonly accepted as a means of reducing fossil-fuels consumption and air pollution. At present, every electric mean of transportation (hoovers, bicycles, scoters, forklifts, cars, buses) is powered by a lithium-ion battery.

This course presents the state-of-the-art in research and development of battery technologies and Battery Management Systems (BMS) used in Electric Vehicles (EV) or Energy Storage Systems (ESS). It summarizes their features in terms of performance, cost, service life, management, charging facilities, and safety.

Given the interdisciplinary nature of automotive engineering, this course prepares graduate students for product design, development, manufacturing and testing in various general fields of engineering: automotive electronics, electrical engineering, electrical electronics, energy storage systems, renewable energy, smart grids. Particular fields of electric vehicles include manufacturing and maintenance of batteries with different chemistries, electronic control units (ECUs), electronic converters, batteries management systems, batteries chargers.

7. Competences *(Proven capacity to use knowledge, aptitudes and personal, social and/or methodological abilities in work or study situations and for personal and proffesional growth. They refflect the empolyers requirements.)*

Specific Competences	- To apply fundamental and specialized knowledge to solve complex technological problems which are specific to Automotive Electronics and Applied Electronics; - To develop engineering solutions for solving technological problems in the fields of automotive electronics, power electronics, and renewable energy systems; - To solve problems regarding the automated processes control encountered in automotive systems and to use electronic controllers; - To apply the knowledge from the field of Applied Electronics in order to perform and complete case studies in the field of dedicated systems for Automotive Electronics;

Transversal (General) Competences	- To define the advanced notions of information technology, electronic circuits and automation for performing quality management; - Responsibly working in a multidisciplinary team with abilities to assume roles specific to different hierarchical levels; - Capacity to identify the need for continuous education and efficient use of information sources, communication resources and training assistance (Internet portals, specialized software, databases, online courses) both in Romanian and a foreign language.

8. Learning outcomes *(Synthetic descriptions for what a student will be capable of doing or showing at the completion of a course. The learning outcomes reflect the student's acomplishments and to a lesser extent the teachers' intentions. The learning outcomes inform the students of what is expected from them with respect to performance and to obtain the desired grades and ECTS points. They are defined in concise terms, using verbs similar to the examples below and indicate what will be required for evaluation. The learning outcomes will be formulated so that the correlation with the competences defined in section 7 is highlighted.)*

Knowledge	*The result of knowledge aquisition through learning. The knowledge represents the totality of facts, priciples, theories and practices for a given work or study field. They can be theoretical and/or factual.* - understanding BMS architecture and balancing techniques; - design and development of BMSs for specific battery packs; - installation and configuration of after-market BMSs on large battery packs; - understanding and application of safety rules in manufacturing and maintenance of battery packs.
Skills	*The capacity to apply the knowledge and use the know-how for completing tasks and solving problems. The skills are described as being cognitive (requiring the use of logical, intuitive and creative thinking) or practical (implying manual dexterity and the use of methods, materials, tools and intrumentation).* - installation and configuration of after-market components and systems for conversion of EVs; - creation of business models and developing new strategies in the field of EVs; - assessing policy plans and regulations for e-mobility
Responsability and autonomy	*The student's capacity to autonomously and responsably apply their knowledge and skills.* - selection and analyzing of appropriate bibliographic sources. - respect the principles of academic ethics, correctly citing the bibliographic sources used. - demonstrates collaboration with other colleagues and teaching staff - promotes/contributes through new solutions related to the specialized field to improve the quality of social life. - identifies sustainable solutions to solve problems in social and economic life. - apply principles of professional ethics / deontology in the analysis of the impact of electric vehicle technologies on the environment. - analyze and capitalize on business opportunities in the field of electric vehicles.

9. Teaching techniques *(Student centric techniques will be considered. The means for students to participate in defining their own study path, the identification of eventual fallbacks and the remedial measures that will be adopted in those cases will be described.)*

For lectures, teaching is carried out through the presentation and questioning methods. Modern teaching methods (video projector) are used for presentation of the course notes, applications notes, videos and demonstrative software applications. The lectures notes and presentations are available to students in pdf format on Moodle platform.

For practical applications, teaching is based on experimentation, combining mathematical modelling with experimental simulation using special development software (Matlab, PSIM, Orcad). Also, to verify the theoretical models, practical measurement will be made on different testing platforms for BMSs using dedicated test and measurement equipments.

10. Contents

COURSE		
Chapter	**Content**	**No. hours**
1	Introduction to Batteries Management Systems (BMSs). History and evolution of BMSs. Applications of BMSs in Electric Vehicles (EVs), Energy Storage Systems (ESSs), portable equipments.	2
2	Modelling and simulation of different battery chemistries: Lead-acid, NiMH, Li-Ion, LiFePO4, NMC. Measuring techniques and estimation algorithms for performance parameters.	2
3	Battery charging methods. Constant Voltage (CV), Constant Current (CC) and Hybrid methods. Charging optimization methods: multistage charging, pulse charging.	2
4	Design and manufacturing requirements for BMS: BMS architectures (single master module, parallel independent modules, parallel slave modules with a master module, series slave modules with a master module). Advantages and disadvantages.	2
5	Voltage, current and temperature measurement techniques. Dedicated integrated circuits.	2
6	Communication protocols for embedded systems (SPI, I2C, One Wire, etc) and industrial systems (RS232, RS485, CAN, USB, Ethernet).	2
7	Passive balancing techniques. Switched power resistors. Advantages and disadvantages.	4
8	Active balancing techniques. Dedicated DC-DC converters with capacitors, inductors and transformers. Energy transfer methods: cell to pack, pack to cell, cell to cell. Switching components: relays, transistors. Advantages and disadvantages.	6
9	Case studies on commercial BMSs. Comparative performance analysis.	2
10	Thermal management for batteries and electronic units. Cooling and heating systems.	2
11	Battery recycling policies and use cases for their second life.	2
	Total:	28

Bibliography:
1. A. Vasile, I. B. Bacîș, "Bazele Electronicii Auto", Editia III, Editura Cavallioti, 2018.
2. I. B. Bacîș, A. Vasile, "Electrician Electronist Auto", Editura PIM, 2016.
3. S. Dhameja, "Electric Vehicle Battery Systems", Butterworth–Heinemann, 2001.
4. M. Ehsani, Y. Gao, S. E. Gay, A. Emadi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles - Fundamentals, Theory, and Design", CRC Press, 2005.
5. V. Pop, H. J. Bergveld, D. Danilov, P. P. L. Regtien, P. H.L. Notten, "Battery Management Systems - Accurate State-of-Charge Indication for Battery-Powered Applications", Springer, 2008.
6. D. Andrea, "Battery management systems for large lithium-ion battery packs", Artech House, 2010.
7. Y. Barsukov, J. Qian, "Battery power management for portable devices", Artech House, 2013
8. G. Pistoia, B. Liaw, "Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost", Springer, 2018.
9. K. S. Hariharan, P. Tagade, S. Ramachandran, "Mathematical Modeling of Lithium Batteries From Electrochemical Models to State Estimator Algorithms", Springer, 2018.

SEMINARY

Crt. no.	Content	No. hours
1	Modeling and simulation of Li-Ion cells during charging and discharging.	2
2	Design and simulation of a Passive BMS for a 4S1P battery pack.	2
3	Experimental Measurements on a Passive BMS for 4S1P battery pack.	2
4	Design and simulation of an Active BMS for 4S1P battery pack.	2
5	Experimental Measurements on an Active BMS for 4S1P battery pack.	2
6	Experimental Measurements on a Master-Slave BMS for 4S1P battery pack.	2
7	Experimental Measurements on a commercial system, Orion BMS2, with 30 cells.	2
	Total:	14

Bibliography:
1. V. Pop, H. J. Bergveld, D. Danilov, P. P. L. Regtien, P. H.L. Notten, "Battery Management Systems - Accurate State-of-Charge Indication for Battery-Powered Applications", Springer, 2008.
2. Y. Barsukov, J. Qian, "Battery power management for portable devices", Artech House, 2013
3. G. Pistoia, B. Liaw, "Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost", Springer, 2018.
4. K. S. Hariharan, P. Tagade, S. Ramachandran, "Mathematical Modeling of Lithium Batteries From Electrochemical Models to State Estimator Algorithms", Springer, 2018.
5. Ewert Energy Systems, "Orion BMS Wiring & Installation Manual", Rev. 4.1.
6. Ewert Energy Systems, "Orion BMS Operation Manual", Rev. 2.1.
7. L. A. Perișoară, I. C. Guran, D. C. Costache, „A Passive Battery Management System for Fast Balancing of Four LiFePO4 Cells", 24th International Symposium for Design and Technology in Electronic Packaging (SIITME 2018), Iași, Romania, Oct. 25-28, 2018.
8. L. A. Perișoară, D. I. Săcăleanu, A. Vasile, „Instrument Clusters for Monitoring Electric Vehicles", 23rd International Symposium for Design and Technology in Electronic Packaging (SIITME 2017), Constanța, Romania, pp. 379-382, Oct. 26-29, 2017.
9. L. A. Perișoară, E. M. Stamati, L. R. Chițu, D. I. Săcăleanu, „Pilot Platform for Remote Monitoring of an Electric Vehicle", 24th International Symposium for Design and Technology in Electronic Packaging (SIITME 2018), Iași, Romania, Oct. 25-28, 2018.
10. B. Anton, A. Florescu, L. A. Perișoară, A. Vasile, R. C. Constantinescu, Ș. G. Roșu, „Methods of Maximizing Power Efficiency for Hybrid Vehicles", Revue Roumaine des Sciences Techniques – Serie Électrotechnique et Énergétique, Vol. 64, Issue 1, pp. 57–62, Jan.-Mar. 2019.
11. L. A. Perișoară, D. C. Costache, I. C. Guran, Ș. G. Roșu, A. Florescu, „Active Balancing for Efficient Management of a 4S1P LiFePO4 Battery Pack", in Proc. of the 11th International Symposium on Advanced Topics in Electrical Engineering (ATEE 2019), Bucharest, Romania, March 28-30, 2019.
12. Ș. G. Roșu, M. Ș. Teodorescu, A. Florescu, L. A. Perișoară, "Study of Operating Conditions Impact on Wireless Power Transfer Systems Performance", in Proc. of the 11th International Symposium on Advanced Topics in Electrical Engineering (ATEE 2019), Bucharest, Romania, March 28-30, 2019.

11. Evaluation

Activity type	11.1 Evaluation criteria	11.2 Evaluation methods	11.3 Percentage of final grade
11.4 Course	- knowledge and understanding of fundamental theoretical notions; - comparative analysis of BMS architectures and balancing techniques; - capacity to apply the theoretical notions to solve practical problems.	Final examination consists of a quiz test, which cover all lectures and contain 20 questions.	60%

11.5 Seminary/laboratory/project	- design and simulation of a BMS for different battery packs; - analysis of the simulation results. - installation and configuration of BMSs for different battery packs; - using test and measurement equipments for battery and BMS maintenance; - analysis of the measured results.	Final examination consists of a quiz test with 20 questions from platforms.	40%
11.6 Passing conditions			
- supporting a test for determining the architecture of a battery management system and describing the required balancing techniques. - accumulating at least 50 points out of 100 points.			

12. Corroborate the content of the course with the expectations of representatives of employers and representative professional associations in the field of the program, as well as with the current state of knowledge in the scientific field approached and practices in higher education institutions in the European Higher Education Area (EHEA)

Taking into account the interdisciplinary nature of automotive engineering, this course prepares graduates for product design, development, manufacturing and testing in different engineering areas:automotive electronics, electrical engineering, power electronics, energy storage systems, renewable energy, smart grids, energy policy.

The lectures present a systematic and detailed description of theory and design of batteries and management systems for them..

The practical activities provide a hands-on look for the modeling of battery cells and the design, simulation, installation, exploitation and maintenance of battery management systems.

The master program provides to graduate students appropriate skills and training for the actual needs and scientific and technological qualifications, of high quality and competitively, allowing them rapid employment after graduation. This fact is consistent with the university policies, both in terms of content and structure, but also in terms of skills and international openness offered to students.

Date	Course lecturer	Instructor(s) for practical activities
10.10.2024	Conf. Dr. Lucian Andrei PERIȘOARĂ	Conf. Dr. Lucian Andrei PERIȘOARĂ

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Date of department approval	Head of department
27.10.2024	Conf. Dr. Serban Georgica Obreja
Date of approval in the Faculty Council	Dean
25.10.2024	Prof. Dr. Mihnea Udrea