THESIS SUPERVISOR'S REPORT

I. IDENTIFICATION DATA

Thesis title:	**Development of an Electrochemical Impedance Spectroscopy (EIS) Measurement System with Active Current Excitation for Online Battery Monitoring**
Author's name:	**Tom Pastuszek**
Type of thesis :	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Measurement
Thesis reviewer:	Ing. Tomáš Haubert, Ph. D.
Reviewer's department:	Department of Electric Drives and Traction

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment	**challenging**

How demanding was the assigned project?

The assigned project was involved, including activities such as design, setting up and conducting experiments, collecting measurement data, interpreting results, and improving processes. Project required student to acquire and integrate knowledge from areas outside of his primary field of study, specifically in battery characterization and electrochemical impedance spectroscopy (EIS).

Fulfilment of assignment	**fulfilled**

How well does the thesis fulfil the assigned task? Have the primary goals been achieved? Which assigned tasks have been incompletely covered, and which parts of the thesis are overextended? Justify your answer.

The thesis satisfactorily meets the set objects. It effectively investigates battery management systems and electrochemical impedance spectroscopy (EIS) for EVs. Thesis presents the design and implementation of a unique low-voltage EIS prototype based on a voltage-controlled current source op amp circuit. Importantly, the student has conducted a thoughtful evaluation of his work and identified areas of improvement and noted that the microcontroller program can be improved to generate more accurate sinusoidal waveforms to improve accuracy. No parts of the thesis are overextended, as the thesis is balanced, avoiding excess in scope and detail.

Activity and independence when creating final thesis	**A - excellent.**

Assess whether the student had a positive approach, whether the time limits were met, whether the conception was regularly consulted and whether the student was well prepared for the consultations. Assess the student's ability to work independently.

The student had a positive approach, was self-motivated to complete tasks correctly and fully, and demonstrated openness to acquire new knowledge and consider different ideas. He was prepared for project meetings. Student demonstrated the ability to work independently, such as setting up the experiments, identifying and using resources, and self-learning to expand needed knowledge and skills to complete tasks.

Technical level	**A - excellent.**

Is the thesis technically sound? How well did the student employ expertise in his/her field of study? Does the student explain clearly what he/she has done?

The thesis is technically sound, presenting the student's measurement methodology and results with clarity. Measured impedance data, illustrated through Nyquist plots, were effectively compared against existing literature to ensure verification across different states of charge and temperatures. Student demonstrated adeptness in analyzing experimental data to formulate insightful conclusions and recommendations, grounded in sound scientific and engineering principles. The thesis clearly articulates its motivation, methodology, experimental outcomes, and conclusions. Student successfully demonstrated the employment of expertise in his field of study.

Formal level and language level, scope of thesis	**B - very good.**
Are formalisms and notations used properly? Is the thesis organized in a logical way? Is the thesis sufficiently extensive? Is the thesis well-presented? Is the language clear and understandable? Is the English satisfactory?	
Content is well organized and easy to follow, main ideas are clearly presented and thoroughly developed. Writing style and English is satisfactory. Work is professionally presented and well formatted. Thesis shows good use of figures and tables to display data. Figures, such as the Nyquist plots, effectively contribute to a better understanding of key ideas and results.	

Selection of sources, citation correctness	**A - excellent.**
Does the thesis make adequate reference to earlier work on the topic? Was the selection of sources adequate? Is the student's original work clearly distinguished from earlier work in the field? Do the bibliographic citations meet the standards	
Thesis cites prior research and work in the field, adhering to proper citation formatting. The bibliography includes 24 sources, including numerous quality peer-reviewed journal articles, such as those from IEEE. Student effectively reviews existing literature on on-board EIS, highlights a gap, and distinguishes the originality and contributions of his work from the earlier work.	

Additional commentary and evaluation (optional)
Comment on the overall quality of the thesis, its novelty and its impact on the field, its strengths and weaknesses, the utility of the solution that is presented, the theoretical/formal level, the student's skillfulness, etc.
Please insert your comments here.

III. OVERALL EVALUATION, QUESTIONS FOR THE PRESENTATION AND DEFENSE OF THE THESIS, SUGGESTED GRADE

Summarize your opinion on the thesis and explain your final grading.

The thesis is coherently structured and provides a comprehensive background on electric vehicles, battery management systems, and the application of Electrochemical Impedance Spectroscopy (EIS) for battery characterization. The student has completed the thesis tasks, successfully measuring the impedance spectra of a lithium-ion battery cell using a novel approach that is appropriate for on-board EIS. Despite the topic of EIS falling outside the student's primary expertise, he has demonstrated the ability to learn and apply new knowledge, as reflected in the literature review and the interpretation of the experimental data. Although the student faced limitations in acquiring specialized benchtop EIS equipment for verification, he effectively demonstrated that the impedance trends relative to temperature and state of charge align with published data. For the thesis presentation and defense, I propose the following questions:

- Could you discuss the main sources of noise and errors in the EIS system and outline the strategies you employed to address these challenges?
- What critical hardware and software considerations were made to ensure the microcontroller-based EIS system's measurements remained accurate and reliable, in line with the Bode 100 analyzer results, and what enhancements could be applied to the current design?
- What significant obstacles did you face while working with the Bode 100 analyzer and the microcontroller in the EIS system, and how did these influence your design choices?

The grade that I award for the thesis is **A - excellent.**

Date: **18.1.2024**   Signature: Ing. Tomas Haubert, Ph. D.