THESIS SUPERVISOR'S REPORT

I. IDENTIFICATION DATA

Thesis title:	Open-source Motion Control on Mid-range and Small FPGAs
Author's name:	Bc. Jakub Janoušek
Type of thesis :	master
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Control Engineering
Thesis reviewer:	Ing. Pavel Píša, Ph.D.
Reviewer's department:	Department of Control Engineering

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment **challenging**

How demanding was the assigned project?

Motion control is a fundamental component of all robotic systems, and electrical drives prevail there and in automotive and industrial servo systems. An electric traction motor prevails over other engines in vehicles with a high probability in the future, as well. Permanent magnet synchronous motors (PMSM) are broadly used there, and their control unit designs call for continuous evolution, reflecting the availability of new components and different applications' needs. Using FPGAs allows the reuse of some parts of digital and software design with different processor systems. On the other hand, more dense FPGAs are pretty expensive, which lowers their potential for use for cost-sensitive applications, enthusiasts projects, and teaching. Thanks to the RISC-V International provided ICE-V Wireless platform; we have the option to port our design used with Raspberry Pi, Xilinx Zynq, and Ti AM43xx to this platform and reuse the same experimental/educational power stage. PiKRON's open-source PXMC library, which is used even on a much broader range of devices, has been used as one software solution. Another option for designing controller software is block design and code generation path with open-source pysimCoder – block diagram editor and real time code generator.
The main tasks of the student's work have been to resolve the problems with the mutual influence of Hall effect-based current sensing on the power stage and adaptation of hardware and software to test solutions on the ICE-V platform with open-source FPGA Yosys tool-chain and NuttX operating system.

Fulfilment of assignment **fulfilled with minor objections**

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.

Jakub Janoušek has designed the current sensor calibration (according to assignment) on the MZ_APO platform, and it has even been integrated into the enhanced Zynq FPGA PMSM interface with RISC-V coprocessor in a frame of parallel work solved by Damir Gruncl. However, updating his work on PXMC or previous Zynq work by using current calibration for current controllers for direct and quadrature components (DQ) in cascaded PMSM controller design has not even been tried. It has been planned to try such an attempt even on the ICE-V platform, even though there has been an expected problem with achieving the required sampling rate. However, on the MZ_APO system, 20 kHz for a commutation (Clarke and Park in both directions) and solid 2 kHz on Cortex-A Preempt-RTLinux for the DQ current controller is an excellent platform for PSMS control and experiments, and this opportunity has to wait for some followup project now. Even the expectation for more comprehensive project documentation has been achieved only partially.
The design of hardware to interface the ICE-V with the power stage and iCE-40 FPGA bitstream configuration driver is a significant result of the work, and all changes have been integrated into the mainline NuttX and pysimCoder projects, which is really valuable outcome of the thesis.

Activity and independence when creating final thesis **B - very good.**

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 started his familiarization and working ahead of time, has been active, brought his own equipment to debug the NuttX FPGA configuration driver, etc. But he has been loaded by his work at a robotic solutions developing company and then due to offering help with the practical seminaries in Computer Architectures course teaching at Luleå tekniska universitet in Kiruna, Sweden. All this negatively interfered with his timeshare for the thesis project.

Technical level	**B - very good.**
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 results are sound, well versioned and critical parts are integrated into related projects mainlines. But there has been space for planned followup steps and their documentation. Even more detailed PXMC based software documentation would help some novices in the project in the future.	

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?	
The thesis structure is logical, contains analysis, describes own work and documents 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?	
The list of references contains 35 entries, all relevant to the projects.	

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.
The results of the projects are valuable and will be reused in followup work, ICE-V related work is periodically announced to the community (https://github.com/ICE-V-Wireless/ICE-V-Wireless/issues/21) and feedback from the platform developers is positive – "This is fantastic news! Please do keep us updated on this." by Eric Brombaugh.

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.

I propose to grade the thesis as **B - very good.**

I suggest to prepare at least some principal model of the DQ current PMSM controller in pysimCoder for the presentation. It should include designed current sensor calibration. Ideally, it should be test to build for MZ_APO and ICE-V. Its testing needs to be left for later time the most probably, when I or some student will find time for it.

Date: 23.8.2024 Signature:

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REVIEWER'S OPINION OF FINAL THESIS

I. IDENTIFICATION DATA

Thesis name:	**Open-source Motion Control on Mid-range and Small FPGAs**
Author's name:	**Jakub Janoušek**
Type of thesis :	Cybernetics and Robotics
Faculty/Institute:	Faculty of Electrical Engineering
Department:	Department of Control
Thesis reviewer:	Roberto Bucher
Reviewer's department:	Extern

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment

extraordina

Evaluation of thesis difficulty of assignment.

The student have to solve problems in different areas, such as hardware and PCB, control of motors, software (including writing of drivers), and he has to work with different operating systems (Linux and NuttX). In addition he had to handle communication protocols (SPI) and integration of FPGAs.

Satisfaction of assignment **fulfilled**

Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.

The student developed PCB for the hardware and programmed all the different software to solve the given tasks. All thw assigned problems have been solved.

Method of conception **outstanding**

Assess that student has chosen correct approach or solution methods.

The theoretical part is well structured and developed. The presentation of PMSM as well as the whole theory of the transformations of Clark and Park, are well presented.
The only remark is related to the continuous integrator used in pysimCoder. For sampling reasons it is always better to use discrete integrators in pysimCoder instead of continuous ones (Figure 10.1).

Technical level **A - excellent.**

Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.

Both hardware and software problems are well realized and discussed.

Formal and language level, scope of thesis **A - excellent.**

Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.

The documentation is complete and well readable. The student demonstrates an excellent mastery of the English language.

Selection of sources, citation correctness **A - excellent.**

Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.

All the sources are presented and well documented.

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REVIEWER'S OPINION OF FINAL THESIS

Additional commentary and evaluation

Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.

The student provides a good and complete thesis.

III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

Summarize thesis aspects that swayed your final evaluation. Please present apt questions which student should answer during defense.

I evaluate handed thesis with classification grade **A - excellent.**

Date: 22.8.2024

Signature: