THESIS SUPERVISOR'S REPORT

I. IDENTIFICATION DATA

Thesis title:	CAN FD Support for Space Grade Real-Time RTEMS Executive
Author's name:	Bc. Michal Lenc
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?

The design of new communication subsystem for real-time system used in critical military and space application for more than 30 years is demanding and requires precise analysis and high quality implementation to fulfill review criteria to be candidate for mainlining. CAN/CAN FD is gaining momentum in space/satellite/probes/rovers applications and RTEMS has been missing general solution. The project implements generic infrastructure with POSIX API, support for multiple applications to open the driver as well as actual support for CTU CAN FD IP core on FPGA SoC and PCI platforms.

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.

All goals has been fulfilled. The submitted code represents almost 3k lines of code and 1k lines in headers. The project together with test applications includes over 7k lines of code. The implemented innovative solution of "Scheduling of CAN Message Transmission when Multiple FIFOs with Assigned Priorities are Used in RTOS Drivers" has been presented by Michal Lenc at international CAN Conference 2024 in Baden-Baden and gained interest from global community and alternative CAN FD and XL controllers designers. The combination with pysimCoder RTEMS experimental port has been demonstrated later as well.

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 has invested lot of time and effort to deliver sound implementation. The project has been demanding and to achieve required quality level there has been lot of feedback sessions and knowledge and ideas collected by me over more than 25 years in the CAN and other industrial communication fields as well as professional experience with architecting medical instruments using RTEMS system has been passed to the student. He has been able to absorb the knowledge base and use it for the project design.

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?

I believe that the production quality for ESA and NASA projects has been achieved, the solution is under review by experts from embedded brains GmbH, Gedare Bloom, Director, Embedded Systems Security Lab Department of Computer Science University of Colorado at Colorado Springs and On-Line Applications Research (OAR) Corporation – main governors of RTEMS system development. The merge request location https://gitlab.rtems.org/rtems/rtos/rtems/-/merge_requests/49, the local CTU project pages https://gitlab.fel.cvut.cz/otrees/rtems/rtems-canfd

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THESIS SUPERVISOR'S REPORT

Formal level and language level, scope of thesis	**A - excellent.**
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?	
I consider project well organized. The overall documentation planned for submission into RTEMS project manual can be found at https://otrees.pages.fel.cvut.cz/rtems/rtems-canfd/doc/can/can-html/can.html, generated source documentation https://otrees.pages.fel.cvut.cz/rtems/rtems-canfd/doc/doxygen/html/index.html. The details has been already discussed with RTEMS core developers https://lists.rtems.org/pipermail/devel/2024-April/thread.html#77761, https://lists.rtems.org/pipermail/devel/2024-May/thread.html#77781	

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?	
I consider work with sources as correct, the licenses has been negotiated with original sources authors and has been adapted into form acceptable for use of the project in RTEMS in actual version and prepared to be reused for NuttX RTOS as well as base to enhance Linux SocketCAN infrastructure and Linux kernel CTU CAN FD driver.	

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 demonstrated mechanism to solve problem of head-of-line blocking/priority inversion prevention for multiple software FIFOs and applications accessing CAN bus through single CAN controller is significant achievement and demonstrated fast propagation of higher priority class messages to the bus confirms algorithmic as well as implementation quality including low latency base of RTEMS system core.

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

Date: 10.6.2024 Signature:

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THESIS REVIEWER'S REPORT

I. IDENTIFICATION DATA

Thesis title:	CAN FD Support for Space Grade Real-Time RTEMS Executive
Author's name:	Bc. Michal Lenc
Type of thesis :	master
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Control Engineering
Thesis reviewer:	Gedare Bloom, Ph.D.
Reviewer's department:	Department of Computer Science, College of Engineering and Applied Science, USA

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment **extraordinarily challenging**

How demanding was the assigned project?

The project involves a deep understanding about the RTEMS real-time executive, the CAN bus protocol, the LinCAN character device driver framework for CAN in Linux, and the CTU CAN FD controller. Upon this understanding, the project defines requirements, a design, implementation, and evaluation of a state-of-the-art CAN stack for RTEMS using pysimCoder generated applications. The span of this project across the hardware and software layers of CAN controller, RTOS services, and test synthesis is impressive.

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.

This thesis provides a comprehensive background of the requisite knowledge in RTOS and CAN bus, explains the design of a solution to integrate CAN into RTEMS and design choices/rationale in a clear and reasonable manner, provides an implementation of an RTEMS driver for CTU CAN FD, and publishes documentation and test results to demonstrate efficacy of the solution. The assigned tasks have been completely fulfilled.

Methodology **outstanding**

Comment on the correctness of the approach and/or the solution methods.

The designed solution is sound, the implementation is useful, and the testing demonstrates the suitability for application use. The tradeoffs in the design are adequately discussed and the methodology shows rigorous engineering and scientific care. The introduction of a priority-inversion management scheme is an impactful solution that has itself been published by the thesis author in a well-known venue for CAN bus topics.

Technical level **A - excellent.**

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

The thesis provides a clear description of the background content with good separation from the new work that has been done. The technical approach demonstrates expertise in the design and implementation of real-time control systems with suitable care made in the tradeoffs between time, space, and real-time considerations such as priority and latency. Whenever a design choice was made that limited the solution, the limitation was clearly identified and justified to provide a clear technical description.

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

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 is well-written and logically organized. The writing provides suitable tutorial to understand the technical details of the work. The description of software structures and interfaces is proper and readily understood. The English is acceptable with only a few minor typos and few grammar problems that do not interfere with understanding the thesis.

Selection of sources, citation correctness **B - very good.**

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 thesis provides suitable references to the prior work. The original work is delineated from the earlier work in the field, although the difference between the new stack and the LinCAN stack is not entirely clear. It may have been worth spending some time to briefly summarize that difference, or to explain the LinCAN in the background section. The bibliography is appropriate to the scope of the thesis, although the real-time priority inversion section (Chapter 4) lacks adequate references to justify some of the comments especially with respect to Section 4.2 (Common Solutions) or to the literature on real-time analysis of CAN.

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.

This thesis is overall of an excellent quality. It brings a novel CAN software stack to a widely-used real-time operating system, and addresses the critical concern of priority inversion in real-time systems. I believe this may be the first practical, published solution for CAN bus priority inversion at the RTOS interface. The solution will have lasting impact and will lead to further work in improvements to the contributed CAN framework and extensions to other protocols compatible with CAN/CAN FD, such as CAN XL. The student has demonstrated a high level of expertise and skill in designing and implementing practical, impactful software for real-world control systems.

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. Pose questions that should be answered during the presentation and defense of the student's work.

This thesis is a strong impactful solution to a pressing need. The author has provided a clear description of the problem, the design of the solution, aspects of the implementation, and testing of the solution. The contribution of the CAN driver framework to RTEMS will have lasting impact.

A question: The RTEMS_CAN_CHIP_STOP ioctl appears to be unsafe by disabling the CAN controller despite other opened instances. Is this a fundamental limitation of the ioctl interface? Do the opened instances resume working when the chip is started again?

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

Date: **11.6.2024** Signature: