PROJE4 Course Manual

Project Smart Energy Devices

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THE HAGUE
UNIVERSITY OF
APPLIED SCIENCES

FACULTY TECHNOLOGY,
INNOVATION & SOCIETY

Contents

1 Project Organization

Instructors:

- Stephen O'Loughlin : s.d.Oloughlin@hhs.nl (Course Organizer)
- Jesse Op Den Brouw : j.e.j.opdenbrouw@hhs.nl
- Ad van den Bergh : a.c.m.vandenBergh@hhs.nl

	Name	**Course Structure**	**Semester**	**Contact Hours**	**Self Study Hours**	**Assesment Method**
PROJE4	Project Smart Energy Devices	Project	2	20	8 per week	Cumulative

Table 1: PROJE4 summary

2 Required Knowledge

Pre-requisites

This project requires a diverse skill set and students should be comfortable with all of the course work in the first 3 semesters of the HHS Elektrotechniek program. However, students should in particular be up-to-date with the material of the following courses:

- UCPROG (micro-controller programming)
- ELEFI1 and ELEFI2 (electronic circuit theory, transistors)
- INGVH3 (project management, requirements and testing)

Co-requisites

Students are expected to be learning the material from the following course(s) simultaneously:

- HFTECH (PCB design)

3 Project Description

The term *Smart Energy Devices* can be used to describe a broad range of products which are aimed at using intelligent embedded technology to improve efficiency and save energy within their specific application. This can include simple products like smart home energy meters, as well as more complicated equipment such as the sensors and controllers within smart power grid equipment and even electric vehicles.

Within the Netherlands, these kinds of products have even found their way into some of our favorite pastimes, such as cycling. According to a 2021 report by the Dutch National Institute for Public Health and the Environment (RIVM)[1], almost a third of the cyclists in the Netherlands use electric bikes (e-bikes), and in virtually all of these e-bikes one can find a smart embedded motor controller.

With this in mind, students are asked to work in groups to design, build and test a sensored brushless-DC (BLDC) motor controller for an electric bicycle.

4 Requirements

The high-level project requirements have been split into three sections. The *project design requirements* place constraints on the final technical product. The analysis and reporting requirements relate to the contents of the final report. Finally, the individual competency requirements assist in guiding individual student development.

4.1 Project Design Requirements

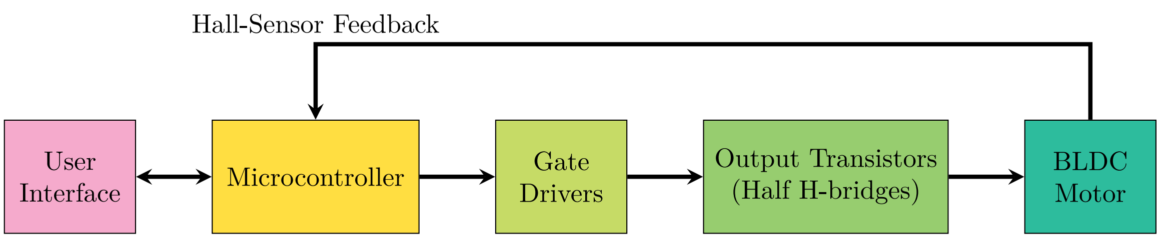

Figure 1: System-level block diagram (not including power supplies)

The basic system for a sensored BLDC motor controller consists of a user interface, a micro-controller, a set of gate drivers, the output transistors, and finally the motor itself with its hall sensor feedback. An example system level diagram (with power supplies omitted) is shown in Figure 1. In order to be successful in this course, project groups must meet the following set of high-level requirements:

1. The motor controller must be able to continuously turn a 24 V, 78 W BLDC motor in a closed loop configuration using hall sensor feedback. (Note: e-bikes typically are driven with higher power motors ($>$ 200 W), however for cost savings students are only provided 78 W motors for testing).

2. The design must use one of the following two micro-controllers in order to generate the motor control signals:

[1] https://www.rivm.nl/en/news/almost-third-of-cyclists-in-netherlands-use-electric-bikes

- RP2040 (Found on the Raspberry Pi Pico board, recommended)
- STM32F103C8T6 (Found on the STM Blue Pill board, not yet tested)

Please note that each group will be provided with a Raspberry Pi Pico board which contains an RP2040 on it.

3. The hall sensor signals must be processed in the micro-controller (i.e. it is not permitted to use an advanced motor driver IC which handles the hall-signals internally).

4. Discrete transistors must be used to control the three phases of the motor (although any additional components such as gate drivers can be implemented using integrated circuits).

5. The final product must be on a custom printed circuit board (PCB) that has been designed and assembled by the student group themselves. *Please note that due to the complexity of properly soldering the QFN-56 package of the RP2040 onto a PCB, this particular component is not required to be part of the final PCB layout and the entire Pi Pico board can be added as an additional hat onto the PCB through an appropriate connector (and similarily with the LQFP 48 package of the Blue Pill micro-controller, although this can be more easily hand-soldered).*

6. The controller must measure the current delivered to the motor and be able to send it to the user interface.

7. The user interface must provide a control input (i.e. throttle) that allows the speed of the motor to be controlled, and must also be able to display the measured speed (i.e. rpm) and current.

Please note that the requirements above are the minimal requirements that must be met in order to achieve passing grade. However, in order to excel and achieve a high grade, student groups must go above and beyond these basic requirements. Students are strongly encouraged to be creative and come up with their own ideas to improve the design.

4.2 Project Analysis and Reporting Requirements

In addition to meeting the high-level design requirements with their finished product, students are also required to record their entire design process and submit this in a formal technical report document. This document must be written in the English language and should include:

1. A clear description of the project goal.

2. A description of the complete system concept design including necessary supporting background information.

3. A detailed list of requirements for all sub-blocks and components in the design (note: these should be created before beginning the detailed design stage).

4. A summary of the technical analysis performed during the detailed design stage, including calculations and appropriate simulations in order to support all design choices for all parts and components of the design.

5. A description of the final detailed design including all schematics and components.

6. Measurement and verification results to show that the design meets the requirements.

7. In-depth analysis of any differences between the simulation and measurement results.

8. Suggestions for improvement in possible future iterations.

Finally, a template for the layout of this final report will be provided on Brightspace, and it is required that the delivered report follows the structure of this template.

4.3 Individual Competency Requirements

In addition to the requirements on the project design, students are also required to demonstrate the following 3 competencies at the indicated levels:

- Analysis (level 2)
- Design (level 2)
- Realization (level 3)

Each student must provide written justification using the STARR method for how they have met the required competencies at the required level. This should be attached as an appendix to the written report.

For more information on the definition of the competencies and their associated levels, please refer to the documentation on www.hbo-engineering.nl (see link in the footnote[2]).

[2] `https://www.hbo-engineering.nl/_asset/_public/competenties/Bijlage-5-landelijk-eindniveau-hbo-elektrotechniek-13-jan-2014-versie-10-2.pdf`

5 Project Timeline

This course is a semester long project with several important dates which are shown in the Table below.

Course Week	Week Monday Date	Activity
1	Feb 5	Kickoff
2	Feb 12	Plan of Approach
	Feb 19	Voorjaarsreces
3	Feb 26	
4	Mar 4	
5	Mar 11	
6	Mar 18	
7	Mar 25	Intermediate Assessment 1
8	Apr 1	
9	Apr 8	
10	Apr 15	
11	Apr 22	
12	Apr 29	Intermediate Assessment 2
13	May 6	
14	May 13	
15	May 20	
16	May 27	
17	Jun 3	
18	Jun 10	
19	Jun 17	Final Assessment
20	Jun 20	Herkansing

Table 2: PROJE4 weekly timeline

6 Assessment and Grading

The *studiewijzer* provides some general information on the grading and assessment for this course in the section titled *Assessment, Grading and Competencies*. In particular it is stated that there will be 4 moments of assessment which will contribute points to the overall grade of each student. These are:

- Week 2: Plan of approach (10 points)
- Week 7: Intermediate Assessment 1 (20 points)
- Week 12: Intermediate Assessment 2 (30 points)

- Week 19: Final Assessment (40 points)

In the sections that follow, some more specific details regarding each of these assessment moments are provided.

6.1 Plan of Approach

The project group must submit a Plan of Approach document to Brightspace which will earn students a maximum of 10 points towards their final grade. The document must contain the following items:

- Clear, concise and complete description of the desired results and objectives of the project along with any necessary supporting background information.
- List of high-level requirements that must be met for a successful design.
- High-level summary of the proposed system design including a block diagram of the system and a written description.
- List of steps and tasks which need to be accomplished in order to reach the desired results
- List of resources needed to reach the desired results
- Detailed planning schedule with deadlines and milestones

The deadline for submission is indicated on the Brightspace page for the course. Students are encouraged to submit their document before the deadline as late submissions will be penalized 10% per day.

6.2 Intermediate Assessment 1

This is the first of two intermediate assessment moments and will contribute 20 points to the final grade of each student. At this stage in the project, students are expected to have written, and to some extent tested, all of the microcontroller code necessary to drive the motor and control the user interface, this includes testing on real prototype hardware.

The assessment will thus take the form of a code review and consist of the following two parts:

- **Written submission** Several days prior to the in-person code review the project group must submit to Brightspace the following items:
    1. Document in pdf format listing all of the detailed design requirements in relation to the software, including both interface and functionality requirements (e.g. what IOs will be used, what is the reset state on the IOs, etc).

2. Well documented and well formatted version of their code in its original file format (e.g. .c, .cpp, .py).
3. Copy of the same code as above but in .pdf format
4. Maximum two page summary of what tests have been completed to date, including any tests on actual prototype hardware in pdf format.

- **In-person code review meeting** Prior to the review meeting, the course instructors will have checked the previously submitted documents and have prepared a set of comments and questions. These will then be discussed during the meeting where students should be prepared to explain their work and design choices.

Students will be graded based on the progress they have made to date, the quality of their submitted work, and their ability to justify and provide support for their design decisions during the in-person review.

The precise deadline for the written submission as well as the date for the in-person review will be indicated on the Brightspace page for the course. Students are encouraged to submit their documents before the deadline as late submissions will be penalized 10% per day.

6.3 Intermediate Assessment 2

The second intermediate assessment has a similar structure to the previous but this time it will take the form of a PCB design review and will contribute 30 points to the final grade of each student.

As in the code review, this assessment will also consist of two parts:

- **Written submission** Several days prior to the in-person PCB design review the project group must submit to Brightspace the following items:

  1. Document in pdf format listing all of the detailed design requirements in relation to the hardware (circuits and PCB).
  2. A zip file containing all PCB related design files (schematic and layout files) as well as datasheets for all active components. This should all be contained in a clearly labeled and organized file structure.
  3. A well formatted pdf file containing pages showing both the schematic and the layout for the PCB design. The layout should be in a clear format such that it can be easily reviewed both from the top level design perspective and the individual layers.
  4. Maximum two page summary of the progress of the project, including the results of any tests on actual prototype hardware.

- **In-person PCB design review meeting** Prior to the review meeting, the course instructors will have checked the previously submitted documents and have prepared a set of comments and questions. These will then be discussed during the meeting where students should be prepared to explain their work and design choices.

Students will be graded based on the progress they have made to date, the quality of their submitted work, and their ability to justify and provide support for their design decisions during the in-person review.

The precise deadline for the written submission as well as the date for the in-person review will be indicated on the Brightspace page for the course. Students are encouraged to submit their documents before the deadline as late submissions will be penalized 10% per day.

6.4 Final Assessment

The final assessment is worth 40 points and includes a presentation, a demonstration and a final report. The expectations and points distribution are as follows:

1. Presentation (10 points)
    - Student groups must give an 8-10 minute presentation that provides an overview of their design and a summary of their results including final performance measurements.
2. Demonstration (10 points)
    - Students groups must provide a live demonstration showing their final design
3. Report (20 points)
    - Students groups must submit their final report including the competencies section (see section 4.2 and 4.3 for details)

A more detailed list of expectations for the different items, as well as a grading rubric will be provided for students on Brightspace.

The deadline for the submission of the report, as well as the schedule for the presentation and demonstration will also be provided on Brightspace. Students are encouraged to submit their report document before the deadline as late submissions will be penalized 10% per day.

7 Project Groups

The project is to be completed in groups of students. Students are required to form their own group during the initial project kick-off session held at the beginning of the semester. Each group should consist of 4 members (although in some cases groups of 3 members may be permitted).

8 Budget and Component Orders

The budget for the project is 100 euros per group (the cost of 1 reasonably sized bare PCB is not included in this). Groups must keep track of all purchased items and include this in their final report.

All component orders must be made through HHS using only approved suppliers (see list on Brightspace). It is highly recommended to choose either Conrad or Farnell when sourcing components as there are no shipping costs for these suppliers.

To place an order:

1. Create a list of all the components in MSExcel using the template available on Brightspace (see the Component Orders tab under General Information).

2. Rename the file with the following format: *PROJE4 2023 Component Order List Group Number.xlsx*, where *Number* is replaced by the number of your specific group as shown in Brightspace.

3. Make a final check of component packages to make sure that they are appropriate for hand soldering.

4. Make one last double check of the component availability and delivery times.

5. Send an email with your complete order list to Zoja Donné (Z.Donne@hhs.nl) and include the course organizer in CC (Stephen O'Loughlin S.D.Oloughlin@hhs.nl)

6. Keep checking with Zoja about delivery times until you receive your components. Don't wait forever for an email saying that they have arrived.

It is essential that students order their components as early as possible in order to avoid delays waiting for components to arrive. Also, before placing an order always remember to check for availability and delivery times.

9 Supervising Instructors

After the kick-off meeting in week 1, each student group will be assigned a supervising instructor. The groups are required to schedule an initial meeting of 30 minutes with their supervising instructor within the first two 2 weeks, to discuss the initial project planning. Following this initial meeting, if desired, groups may schedule additional meetings with their supervisor to help with technical and/or other questions, up to a maximum of once per week for 30 minutes each.