Aalto University
ELEC-E8002 & ELEC-E8003 Project work course
Year 2017

Project plan

Project #34
Wireless Heartbeat Monitoring System

Date: 24.1.2017

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Information page

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Project manager
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Official Instructor
Simo Särkkä

Other advisors
Miika Arvonen (Medical doctor interested in our project)

Starting date
5.1.2017

Approval
The Instructor has accepted the final version of this document
Date: xx.1.2017

1) Background

Monitoring the heartbeat and breathing rate play important roles in healthcare. These signals provide valuable information on what is going on in the body. The stethoscope has been used for hearing the heartbeat and movement of lungs, but in today's technological world this is not a very sophisticated way.

Our project aims to build a prototype device for heartbeat monitoring. The heartbeat monitoring system will sense the heartbeat from a MEMS accelerometer-magnetometer-gyroscope sensor. The device will then process the signal and send it wirelessly to a laptop or a mobile phone where the heartbeat can be continuously monitored. The device will be battery-operated and we will provide calculations and a plan for further product development to make it a professional, very low-power product that is handy in size.

Healthcare is a big industry and the companies in the field would definitely be interested in this kind of high technology innovation. With some product development, we could turn the prototype we are to build during this project into a real product. Such product could be sold to, for example Suunto or Polar type of company, or one could form a startup from this application.

2) Expected output

The main expected output from the project is a functional prototype to detect user heartbeat rate from a person staying still, based on the MEMS sensor data, and send it wirelessly to a user interface application on a laptop or a mobile phone. In the hardware point-of-view, a similar commercial device could be the MetaWear CPRO. Optionally, the project may also include breathing rate measurement.

The expected performance of the device includes accurate measurement, one second rate of measurement data transmission to host device and low power consumption. Moreover, as the device utilizes the Bluetooth low energy protocol, the following certifications will have to be considered: FCC (Federal Communications Committee, US), European Commission (R&TTE) and IC (Industry Canada). This is necessary in selling the product within the corresponding market areas. Furthermore, for a Bluetooth device there is a need for Bluetooth compliance and certification. Note that, although the project will attempt address this issues, the qualification result is not part of the project outcome.

The project is part of bio-signal processing and movement-tracking research work. The expected user for the device can be any individual (i.e. human). User experience related requirements includes the final product should be lightweight and small enough to be attached near the chest area without causing discomfort. User can get the data via the provided interface software running on handheld smartphone device or a host computer. The data presentation will be both in graph and values with respect to time. Note that, the prototype hardware expected as a project outcome can be relatively large as compared to the final product envisioned. However, the choice of components for the development will be dictated with such consideration.

The prototype device will be demonstrated using the development kit for the selected processing device. And the data will be presented using Matlab. However, if time allows demonstration could be made with smaller size custom PCB and user interface software developed for this purpose.

3) Phases of project

Getting organized and learning

Learning the project topic requirements and goals as well as the practices on how we plan to meet during the rest of the project. This phase also includes agreeing on the platforms to use for the project, selecting the project managing and division of the work package responsibilities.

Implementing project plan

The project plan needs to be implemented before 26.1.2017. It was carried out mostly during the week 2. We shared the topics from the project plan for the group members to work on and met the instructor on 17.1.2017 with the first version of the project plan. According to the comments from both the instructor and group members, the document was finished during the week 3.

1st milestone (M1)

We have gained understanding about the project topic, we have agreed on goals, practices and platforms, group members have roles for the work packages and tasks and we have finished and returned the project plan. We also have some of the design decisions made.

Brainstorming: design decisions

We have to choose a microcontroller part to be used for our project (Raspberry Pi, Teensy 3.2. and the NRF52 development board are the initial suggestions), as well as the wireless communication protocol (WiFi or Bluetooth) and the sensor chip (containing accelerometer, gyroscope and possibly magnetometer, MPU-9250 is suggested).

Ordering the parts and getting premises for technical work

Will need to provide the parts list for the instructor in order to get the parts ordered. We will also have to find premises to do the actual technical work. The instructor helps with providing meeting room and a small lab space and a place to store our parts in Otakaari 3. Markus has access to a workshop space in the TUAS-building.

2nd milestone (M2)

Design decisions made, parts and premises available.

Learning to use the development board and assembling prototype

This phase includes hardware wiring, implementing the sensor-reading, communications and data plotting software as well as testing and debugging.

3rd milestone (M3)

First prototype assembled and we know how to use the microcontroller.

Software development

Write software to configuring the sensor, read data and send it wirelessly to the plotting software.

4th milestone (M4)

Proof of concept. We should have a prototype that reads the data from the sensor and wirelessly sends it to a PC or a mobile phone and the raw data is plotted on the screen.

The second planning and learning phase

Recalling to the project goals. We will have to brainstorm to find out if there is a need for another hardware design or will the proof of concept design be sufficient.

Business aspects

Doing the Business aspects assignment.

Making a real product (documentation)

If we were to make this a real product (which we are probably not going to, during this course at least), which kind of regulations and design features would have to be taken in account. How much would the power consumption be and what would approximately be the size of the device if we were to make the real product implemented with the same sensor and microcontroller chips and features, without the big development board. We could also document on how good A/D converters are required and how much memory is needed. All this will be included in the final report of our project, but we must start documenting it when we begin to understand these aspects with our prototype development.

Finalize the prototype

We should continue with the device, either with a new design or developing the previous proof-of-concept design. We should finish the hardware design and possibly 3D-print an enclosure.

The data needs to be filtered in order to get the heartbeat and optionally the breathing rate. Simo will provide help with the signal processing with some MATLAB code. Processing of the signal is preferably done already in the embedded system and not on PC. One idea is to also calculate the beats per minute reading.

5th milestone (M5)

The same or a new, fancier prototype that that reads data from the sensor, filters the heartbeat (and possibly breath rate) sends it wirelessly to a PC or a mobile phone. Data is both plotted as graph and as an beats per minute reading.

Presentations

Presentations with our device in the final gala.

Reporting

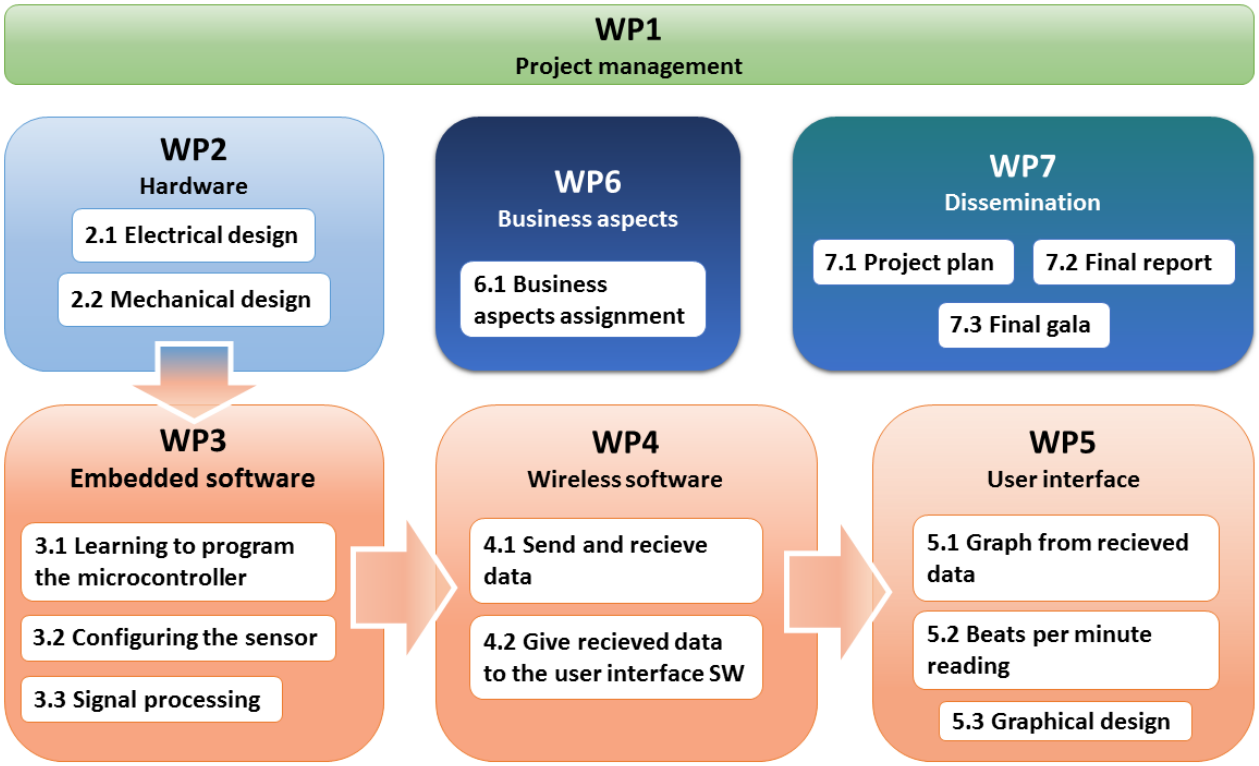
Finishing all the documentation work required.

6th milestone (M6)

Project completed

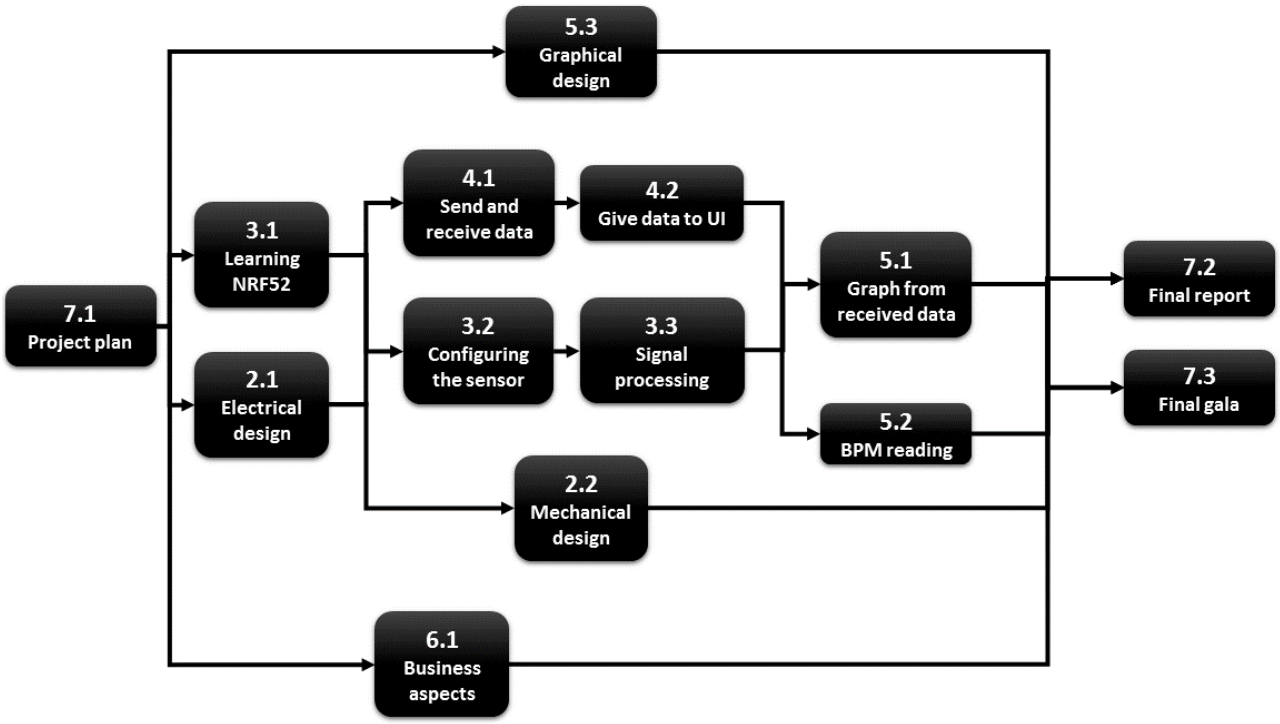
4) Work breakdown structure (WBS)

Figure 1. The work breakdown structure.



5) Work packages, tasks of the project and the schedule

Figure 2. The project path.



5.1) Work packages and estimated hours

WP1 - Project management *(50h)*

Markus Huuhtanen is responsible for this work package. This work package includes following everyone's work and taking care that all tasks have been assigned to someone and are started in time. If the project is not on schedule, the project manager reminds the corresponding people. Project management work package also includes reporting to the instructor and arranging meetings and taking care of component orders.

WP2 – Hardware *(60h)*

Markus Huuhtanen is responsible for this work package.

Task 2.1: Electronical design *(25h)*
This task includes designing and implementing the electrical connections in the sensor and the embedded CPU development board. Choosing battery and possible power switch also belong in this task.

Task 2.2: Mechanical design *(35h)*
This task is about designing and implementing the enclosure design and the mechanism to attach the heartbeat sensor to chest.

WP3 - Embedded software *(150h)*

Sami Mahamoed is responsible for this work package. The signal processing is preferably done in the embedded software.

Task 3.1: Learning to program the microcontroller *(40h)*
Gaining access to the microcontroller software via an IDE. Getting first codes to work (LED-blinks, for example) and searching for useful libraries and already-made code that are available online.

Task 3.2: Configuring the sensor *(80h)*
Reading data from the accelerometer, magnetometer and gyroscope via I2C or SPI and storing it to an useful format in the microcontroller.

Task 3.3: Signal processing *(30h)*
Bandpass filtering and detection of maxima and minima of the raw signal from the sensor. Beats per minute can be calculated from these.

WP4 - Wireless software *(100h)*

Ajinkya Gorad is responsible for this work package. It includes software implementing in both embedded platform and PC/mobile phone sides.

Task 4.1: Send and receive data *(80h)*
Send the processed signal from the embedded platform wirelessly and receive it in a PC or a mobile phone. We plan to use the low power bluetooth.

Task 4.2: Give received data to the user interface software *(20h)*
After receiving the data wirelessly, it needs to be provided to the plotting software.

WP5 - User interface *(100h)*

Antero Erävuori is responsible for this work package. It includes implementing plotting software and graphical design on the PC or mobile phone, where the user can view the heartbeat.

Task 5.1: Graph from received data *(70h)*
View the processed signal as a graph in the screen of the PC / mobile phone.

Task 5.2: Beats per minute reading *(5h)*
Also view the beats per minute reading (heartbeat and optionally the breath rate).

Task 5.3. Graphical design *(25h)*
Design the outlook of the application where the data is viewed.

WP6 - Business aspects *(70h)*

Ajinkya Gorad is responsible for this work package.

Task 6.1: Business aspects assignment *(70h)*
Implementation of the assignment.

WP7 – Dissemination *(120h)*

Markus Huuhtanen has the main responsibility in this work package, although the work in each task is divided to all group members.

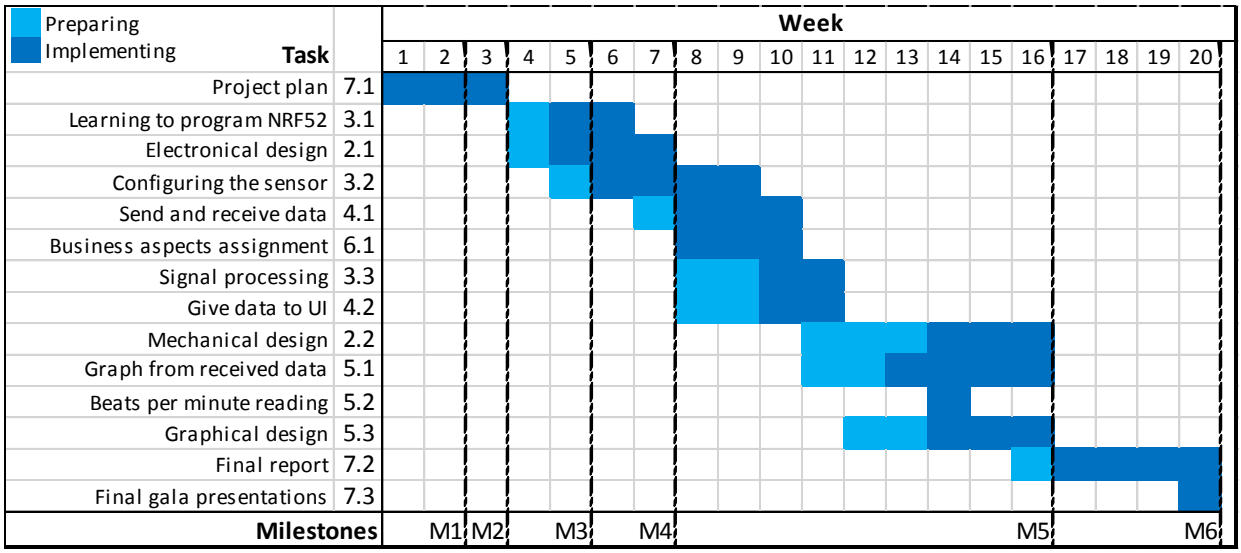
Task 7.1 Project plan *(45h)*
Doing this document.

Task 7.2 Final report *(55h)*
This report will include all the information of our project and point out a plan on how to make an industrial product out of this prototype design (electrical, mechanical and software designs, approximate specifications of the product, regulations needed to take in account etc.)

Task 7.3 Final gala presentations *(20h)*
Self-explanatory

5.2) Detailed schedule

Figure 3. Gantt chart of the project.



6) Work resources

6.1) Personal availability during the project

Table 1. Number of hours available for the project (excluding lectures and seminars) per week.

	Markus Huuhtanen	Ajinkya Gorad	Sami Mahamoed	Antero Erävuori
Week 1	6	5	6	3
Week 2	10	7	8	4
Week 3	5	9	8	4
Week 4	5	9	8	5
Week 5	10	10	8	8
Week 6	2	1	8	8
Week 7	6	9	8	4
Week 8	8	2	4	10
Week 9	10	9	4	10
Week 10	10	10	10	10
Week 11	10	9	10	10
Week 12	10	9	10	10
Week 13	2	3	10	8
Week 14	20	9	10	8
Week 15	10	12	10	4
Week 16	10	12	10	4
Week 17	10	9	10	8
Week 18	10	9	10	10
Week 19	3	12	10	8
Week 20	9	12	10	8
Week 21	3	9	10	8
Total	**169**	**176**	**182**	**153**

6.2) Personal goals

Markus Huuhtanen

I already have a good experience in the Arduino world as well has hardware electronics, both from school and work. However, I plan to learn more about making a real product professionally. Also I have plenty to learn from the wireless communication.

My main goal, however, is in the project management. I have been managing most of the group projects in university courses before and I also have leadership experience from being the chairman in an organization. Still I think plenty to learn in managing skills and in keeping the group work in schedule without being too strict. Leading without authority is going to be my biggest challenge during this course.

Ajinkya Gorad

For me working in a group with all members having a good background knowledge is a new experience. I have good experience with getting things to work when they don't, but with a lot of patience and time. The new thing to learn for me will be the processing on the signals to get the heart-beat and breathing rate and the biomechanics related to it. For me challenge is to successfully bring the project to the final stage end desired by the user within the stipulated time frame as planned.

Sami Mahamoed

I have good background in embedded systems and software development. As a result of this course, I want to learn proper techniques, tools and procedures that are helpful when executing a projects.

Antero Erävuori

Mostly I want to learn to make working in a team efficient. I also want to learn more about many skills in which I still don't have too much experience in, for example signal processing and embedded device development in general. I really want to get familiar with the big picture and have at least intermediate understanding of all the aspects included in the whole project.

7) Cost plan and materials

The project budget will be handled in such a way that, required expenses will be requested from the instructor. Instructor approve the order or provide the required items or services himself. A selected team member will record this transaction for future reference. The instructor mentioned that it is necessary to keep the development cost under 1000€.

Table 2. Cost estimation for our project.

Description	Order Number	Quantity	Unit price	Total price
NRF52-DK	1490-1053-ND (Digi key)	2	37,43 €	74,86 €
SEN-13762	1568-1420-ND (Digi key)	2	14,35 €	28,7 €
Micro usb cable	Q 853-ND (Digi key)	2	2,22 €	4,44 €
Other material expense			40 €	40 €
Shipping			0 €	0 €
Other expenses			20 €	20 €
Total				168 €

8) Other resources

Markus Huuhtanen is assistant in Kimmo Silvonen's Electrical Engineering Workshop course. Using the premises and equipment (3D-printers, for example) there will be possible to some extent. However, we are not able to work there when the place is crowded by the workshop course students.

There is also some equipment available in the Rakentajanaukio 2C room R003/F323 which we can ask to use if necessary. We will be primarily holding out equipment in that room in a box. Whenever needed, we can take parts elsewhere (home, for example, for software development), but this will always have to be notified in the telegram chat.

Our instructor, Simo reserved us the Rakentajanaukio 2C room R003/F254 for weekly meetings for the semester.

9) Project management and responsibilities

Project manager

He follows everyone's work and takes care that all tasks have been assigned to someone and are started in time (according to the project schedule). If the project does not seem to be in schedule, the project manager reminds the group about that. The project manager will be reporting to the instructor and will be arranging meetings.

Instructor

The main responsibilities of the instructor includes: Facilitate premises for meeting and technical work, provide guidance when necessary, provide support on technical difficulties, supervise the team if proper procedures are used while running the project and order parts required by the project.

Other advisor

Miika Arvonen is a medical doctor interested in our project. We will be discussing with him about the possible applications and our findings with the device.

Work package leaders

Hardware

Hardware WP leader will take care that electrical design (electrical connections, wiring, possibly a PCB and battery) are planned and implemented properly. Also the mechanical design is included in this responsibility, including planning and implementing both the enclosure of the device and the mechanism to attach the sensor to the chest.

Embedded software

This part of the application will be implemented on the embedded hardware. The work includes: reading analog values, implementing bandpass filter, implementing algorithm to determine heartbeat rate as well as breathing rate from the measured values and provide API for access to the measured heartbeat and breathing rate values.

Wireless software

In this WP, we write software to send the processed and raw data in packets to the receiving device (Laptop/Smartphone) via embedded hardware Bluetooth Low Energy (BLE), and to receive the data in an interface on the device for further processing, displaying/plotting, and logging.

Business aspects

Takes the responsibility to everything that has to do with the business aspects exercise.

Plotting software

Plotting WP leader is responsible for implementing the ways of displaying the measured information by making a graph from the data as well as providing a reading of beats per minute. He is also responsible for the user interface design and implementation.

10) Project Meetings

Project meetings will take place every Tuesday with all group members agreed to a time and place. Default time 4pm at F254. Additional desired meetings will be organized through the communication via chat. Time in the meetings will be spent in discussing the plans and issues with the instructor and the work completed until time with a memo for every meetup, stored in google drive.

11) Communication plan

The team will use several tools for communication discussed below.

Project Management Tools

As primary work management tool Trello will be used to track work progress. On weekly meeting project manager will supervise the status of previous tasks and distribute new tasks to team members. While executing weekly tasks, team members will utilize Trello board to reflect the status of each task.

Version control repositories

All documents and permanent material will be stored within the project Google Drive folder. Source codes and electrical and hardware design files will be stored in Git version management system hosted by github.com.

Day-to-day communication

An application called Telegram will be used for day to day communication. Moreover, more formal messages will be communicated via email. Additionally, Doodle could be used for scheduling appointments outside the normal meeting time.

Communication with Instructor

Instructor will have accesses to all communication tools used by the team. In addition, the instructor can attained the weekly meeting or any other meetings when necessary.

12) Risks

Table 3. Risk analysis.

Risk	Description	Likelihood	Impact	WPs involved	Mitigation strategy
Breaking of components	Delays in hardware testing which also affects the practical testing of software	Medium	High	WP2-WP4	Having sufficient supply of spare parts
Delay of material deliveries	Delays in hardware testing which also affects the practical testing of software	Medium	Medium	WP2-WP4	Early planning of material needs and ordering
Team member not able to finish critical tasks in time	Delays possible in every work package and a possibility of a time consuming bottleneck affecting the schedules	High	High	WP1-WP7	Not putting too much pressure and workload on only one team member.
Team member missing a scheduled meeting	Team member is not able to express his/her opinions and has to be briefed at a later time.	Low	Low	WP1	Making sure that everybody is aware of the decisions and plans made in the meeting. They should also be able to participate in the decision making.
Budget is over exceeded	Further hardware purchases are not possible, biggest threat for the making of a refined prototype for the gala	Low	High	(WP1) WP6 WP7	Making a good plan of the needed materials and not making hasty decisions
Not streamlining the work processes	Divided work cannot be done in parallel if there are constraints in the progress of other WPs	Medium	Medium	WP1-WP5	Making a good project plan, organizing the required process phases in a meaningful way and assigning tasks correctly.

13) Quality plan

Project manager is partly responsible of the quality as he needs to monitor the general progress of the project. He also needs to make sure that everything is done in a unified and consistent manner to avoid too much of ambiguity and inconsistencies. Project manager should give clear tasks to complete for each project member but also make sure that the workload for one person is not too demanding.

Problems should be brought up immediately as they emerge because if this is delayed the problems cumulate much further before it's taken into consideration. This means that the underlying problem could mean changes in the previous work done and thus taking a considerable time of work to correct the problems in the past work.

There should be frequent design reviews made by other group members to reveal errors and also to ensure the consistency of the work throughout the project. Code should be reviewed at predetermined points (e.g. after every submodule or a set of functions). Software requirements and testing for the code should be planned well and implemented before the actual work and this should involve all of the team members.

14) Changing this plan

Any part of this project plan can be changed during the project if all the group members agree on that. Preferably these changes will be agreed in a meeting, but since it is difficult to have everyone present in all of the meetings, the telegram group chat will be a valid communication channel as well. This adds flexibility if we face a situation where we all think that some other way of acting would be better than the one described in this document. However, every group member should agree on the changes. In case of conflict, we will contact the instructor or other course staff to solve the situation.

If changes are obvious or they can clearly be seen in the telegram group chat, no other documentation will be needed. Major changes can be documented in a meeting memo or other written document if seen necessary.

15) Measures for successful project

The project's final outcome will be evaluated by the following factors:

- How close did we get to a fully functional piece of equipment?
- How refined is the final prototype in terms of design and usability?
- How well was the project documented?
- What is the quality on hardware (robustness, energy efficiency, suitability for the intended use environment), considering it is a prototype?
- What is the quality of code/software (bugs, clean code, etc.)?

The project process will be evaluated by the following factors:

- Keeping up with the schedule
- Documentation of the project process (meeting memos, Trello board)
- Staying on budget
- Overall team satisfaction
- How well the individual learning goals were met
- How well did the team communicate during the project