PROJECT PLAN FOR THE "AUTOMATIC SHUTTLE CONTROL SYSTEM"

D-01.A.00-A

Release 3.0

RELEASE NOTES

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01.11.2011	0.2	- Added Risk analysis. - Corrected some grammar. - In “Loss of data”: changed “Cause” to “Description”.	Andreas Vander Eirik Nordstrand
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28.05.2012	2.4.1	-Updated project model - Update planned and spend work hours	Mats Strand Sætervik
28.05.2012	3.0	-Spelling and grammar -Removed phone number and e-mail. -Finalized document	Eirik Nordstrand

ABOUT THIS DOCUMENT

In this document, we will present the project work flow, goals and guidelines. The group, advisors and employers will be presented.

The documents in this project will contain a lot of terms, for example all the different terms on a loom that might be difficult for some of our readers to understand, while others will understand them intuitive. The document “Term list” (D.07.A.06-A) lists every term that is relevant to this project.

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INTRODUCTION

The purpose of the project plan is to have all the important information gathered in one document. The plan goes through how the progression on the project will be, and is also a tool for the project leader and the other members in the group. The project leader uses the project plan to schedule and keep control of the needed resources, while the other group members uses it as an overview and description of the tasks that needs to be done, which members perform which tasks, and when the tasks should be done. The project plan is developed, and will be changed, constantly through the phases.

BACKGROUND

The employer of this project is Tronrud Engineering AS, located at Eggemoen in Ringerike (Norway). The company was established in 1977 by Ola Tronrud [3]. They are the leading provider of cutting edge technology, and their vision is to be the leading provider of advanced technology and "putting ideas into practice"[4].

Their values are [5] :

- Respect
- Quality
- Responsibility
- Cooperation
- Courage

THE GROUP

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Location: Notodden

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Discipline: Mechanical engineering, product development
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ORGANIZING OF THE PROJECT

For a project to succeed, it's important that there's no doubt inside the group what position they have. An organization chart is illustrated in Figure 1. The key positions for this project are:

- The customer
- Project leader
- Advisors
- Group leader
- Project group

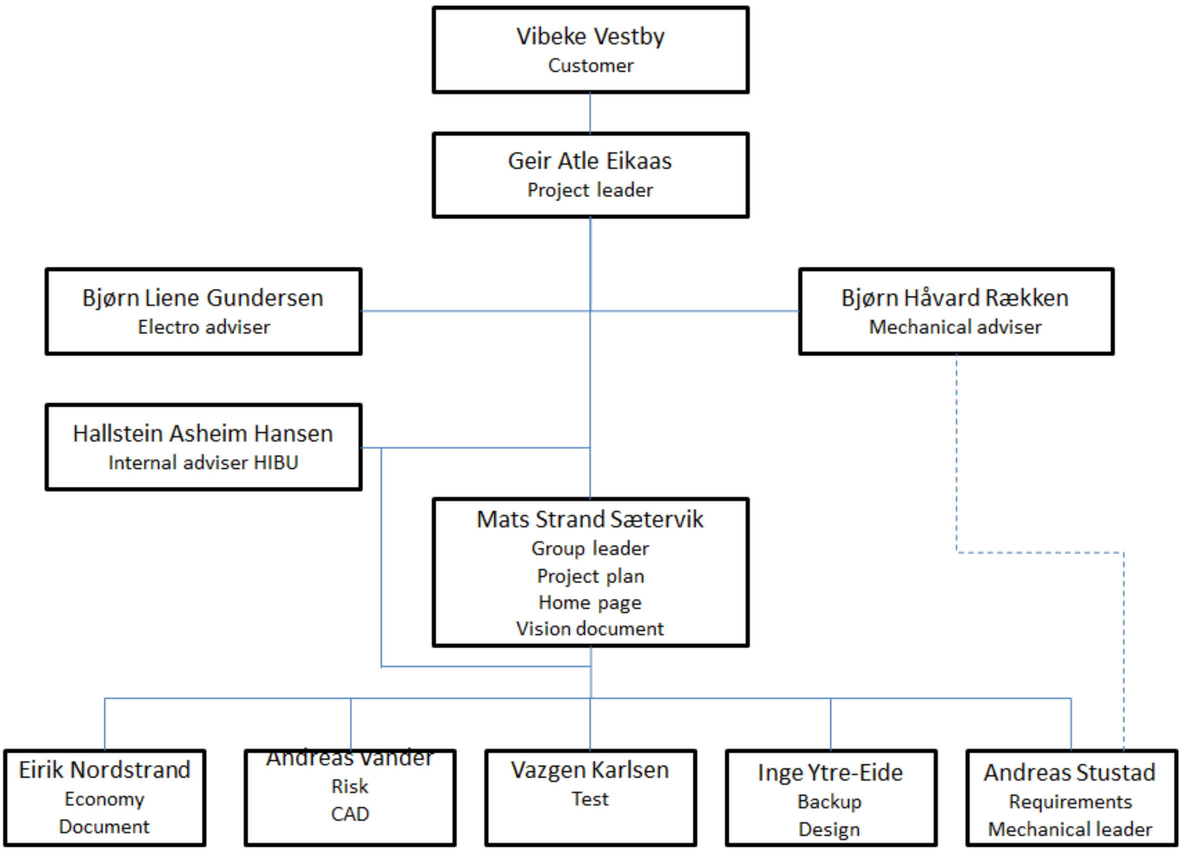

Figure 1: Organization chart

ASSUMPTIONS

Assumptions are going to describe the conditions for the project.

- Each member of the group has to work approx. 600 hours with the project. That means our group has to work a total of approx. 3600 hours. Most of this time is allocated at the later part of the project.
- Papers and presentations must be ready for viewing to scheduled dates and times.
- The product must satisfy the requirements from the customer.
- We must finish all the necessary work before the dead lines.

ASSIGNMENT DESCRIPTION

Through the last couple of years, Tronrud Engineering has been working with the development of a new product, which is based on the TC1 model. The new model is called TC2.

The looms are made with three different widths, where the widths of the warp threads are about 1, 1.5 and 2 meters. The current solution today is manually to push the shuttle with the weft thread between the warp threads. Some of the warp threads are lifted up by the heddle, so that the shuttle gets some of the warp threads over and under. The shuttle leaves the pick behind it.

Our job is to design and build an automated shuttle where a mechanical arm automatically runs through the warp threads and retrieves one of at least eight different threads.

There will be some challenges in this project. The main challenge is the lack of available space. As described in the vision document, the module will need to be placed inside a defined area which is relatively small. We will also have focus on the security on the system, so it won't harm the hands and fingers of the weaver. Also, the module must be able to be attached to the TC2, even if it was originally purchased without this mechanism.

PROJECT OBJECTIVES

PREREQUISITES

- The project has to be feasible.
- We have to make the assumption that our problem does not exceed today's technological possibilities.
- The people that are working on this project must have relevant technical education/knowledge.
- If we are going to develop a prototype we have to get financial backup from Tronrud Engineering, this is more likely to happen if we deliver a good pre-study.

PROCESS OBJECTIVES

- Developing a design for the project.
- Investigate different technological solutions for our product.
- Acquire the right competence to complete the project, this will include :
  - Project planning and group cooperation.
  - Developing requirement specifications.
  - Developing test specifications and performing tests.
  - Learn about the TC2's components.
  - Working with customer and customers' demands.

RESULT OBJECTIVES

- Implement 3 presentations.
- Deliver documentation that will contain information about our work and product.

EFFECT OBJECTIVES

- Complete a prototype that satisfies the customer/customers and Tronrud Engineering.
    - Tronrud Engineering wants a product that, in the future, will give them profit.
    - Deliver a product that will have the potential to make the weaving process on the TC2 a little simpler.
- Our product will do the job at least as fast as a human.
- A mechanical shuttle automatically runs through the warp threads.
- The system must contain 8-12 thread reels with different colors.
- The system must automatically attach the correct thread to the gripper every time.
- The thread is to be cut each time the shuttle runs through the warp threads.
- The weaver manually uses a comb called the reed to push the weft thread into place after each pick operation.
- The automatic sequence is repeated.
- The group will have acquired competence regarding project and team-based work methods.

PROJECT DOCUMENTATION NUMBERING

This project has standardized numbers on every document,, activity requirement and test. The standardization has been generated for easy understanding and indexing of everything that will be produced throughout the project. The structuring of the numbering are divided into 5 sections.

Type of activity	Module	Priority	Number	Field
D	01	A	00	A

Table 1: Numbering structure overview

The table above shows how the standardization is structured. The number is written: "D-01.A.00-A". The number gives us the information that it refers to a document, connected with module number 1, with priority A (priorities is given from A to C, with A as the highest). The number is 0, in the A in the field column shows that it is in the administrative department.

The numbering can have 3 different types of activity.

T	Test
R	Requirement
D	Document
A	Activity

Table 2: Activities

The project has also been divided into modules, both for the main documents and the parts of the system.

Module number:	Explanation
0	The entire system
1	Project plan
2	Requirement specification
3	Test specification
4	Vision document
5	Activity list
6	Risk analysis
7	Term list loom
8	Economics
9	Use cases
10	Gripper
11	Gripper arm
12	Feeding mechanism for gripper arm

14	DAC circuit
20	Thread selection system
21	Thread cutter
22	Thread feeding system
23	Thread holding system/spool holding
30	Control unit
31	Sensors
40	Casing

Table 3: Module numbers overview

The table above shows the module numbers. Main documents are given module numbers, zero to nine. The rest of the modules are parts to the system. The module numbers for the parts are divided into groups, were the gripper with surrounding components are numbered 1x (10-19. Thread management is numbered 2x (20-29). The control system is numbered 3x (30-39) and the casing, the casing for our system, is number 40. The "holes" in the numbering are placed on purpose, in case we need more modules in the system.

The fourth part in the standardized number gives the number of the document. Numbering is individual for the different types of activities.

The last part of the number gives us the field.

Field	Explanation
A	Administrative
E	Electric
M	Mechanical
EM	Electric and mechanical

Table 4: Field overview

This numbering system will be used throughout the project.

PROJECT MODEL

In this project, we have decided to use the Rational unified process (RUP) project model[6, 7]. This is based on our timeline. We have also looked at waterfall and spiral project models.

The problem with the waterfall model is that we need to establish all requirements before we start the designing and construction of the product. In other words, we have to know exactly what and how we were going to make our product at the beginning.

Spiral goes like a waterfall several times and includes the full waterfall. That means that the project goes like this: Requirements->Design->Construction->Test, and then returns back to start at least 2 times. I.e. it has 2 iterations. The problem with this is that our timeline doesn't give us the time needed since we need to deliver design plans before the beginning of March to be able to get a prototype up and running.

Therefore we went with RUP. This model contains 4 phases called inception, elaboration, construction and transition. Within all phases we have 6 disciplines, which stretch over the whole project.

- Business modeling.
- Requirements.
- Analysis and design.
- Implementation.
- Test.
- Deployment.

For our project, the business modeling and deployment is mostly taken care of by Tronrud Engineering, and therefore should not be a big part of our project.

RATIONAL UNIFIED PROCESS

This project is planned by using RUP (Rational Unified Process), with inspiration from UML (Unified Modeling Language) for generation of use cases and activity diagrams. The reason why we have used UML just for inspiration instead of a standard is the "simplicity" of the project. This project has only 4 use cases, and therefore the need for UML is limited.
The different phases will have 1 or more iteration in this project.

INCEPTION PHASE

In this phase, it's important to get the same understanding of the product as our employer, Tronrud Engineering. This is done with meetings and generation of a product vision document. This document is the foundation for the development further on. It also gives a good indication of our requirements that we also should generate during this phase.

Most of our higher priority requirements are generated in this phase, as direct wises from Tronrud or requirement that we see that needs to be defined before we move on. Another important part of this phase, is the mapping of risks: Financial, health/security and availability of parts and knowledge.

ELABORATION PHASE

Here we start designing the product in modules at the beginning. Discussing different solutions and researching them. Our product has been divided into 10 modules. This makes it possible to work with the modules separately and parallel. This gives us room for error, i.e. if one module needs more time to be designed, this will not delay the whole project. To make our time framework, this phase will include very little of the final programming for part ordering reasons.

In this phase, we test each module separately, integration tests and system tests comes in the construction phase. These tests will mostly be done in software (SolidWorks etc.). If hardware and parts are available, test should be done on them in a final stage of this phase.

Specific reports and plans for elaboration phase:

- Plan for first elaboration (D-01.A.16-A)
- First elaboration report (D-01.A.24-A)
- Plan for second elaboration (D-01.A.19-A)
- Second elaboration report (D-01.A.25-A)

CONSTRUCTION PHASE

If we are able to keep our timeline, we should now have parts available to build our product in this phase. It's very important here to do integration tests as fast as possible to exclude errors in the final system tests.

Specific reports and plans for construction phase:

- Plan for first construction (D-01.A.26-A)
- First construction report (D-01.A.29-A)
- Plan for second construction (D-01.A.28-A)
- Second construction report (D-01.A.36-A)

TRANSITION PHASE

The transition phase is the final phase of the project. This is the "delivery" phase with the transition from development to production. For us, that mean final adjustments of the final product. Our iteration phase will start right after the hand in of our bachelor document. Therefore the transition phase can be used to fix minor glitches and prepare the final presentation.

Specific plan for transition phase:

- Plan for transition (D-01.A.32-A)

The group has chosen to work after RUP project model. We will in this chapter determine an overview over the project`s planned process. The specific tasks are specified in the “activities” (D-05.A.04-A), and illustrated in the Gantt diagram.

Each phase is divided into business model, requirements, analysis, design, implementation and test. For the inception phase the group hasn’t found it necessary to plan or complete the implementation and test.

In the beginning, the group was planning to complete all 4 phases, one iteration in the inception phase, three iterations in the elaboration phase, two iteration in the construction phase and one iteration in the transition phase. We did some changes in the elaboration phase and merged the two last iterations. The reason why we did this was because we did not get time to finish the design in time. The construction phase was divided into two iterations. The first iteration is main task is to complete all the designs and order the parts. The second iteration is to construct the parts and test the module, separately and together.

Our Gantt (Attachment 1) shows the different phases and iterations, sorted by start and end date.
This is our planned progress. Dates for presentations and project delivery are set from Buskerud University College (BUC).The deadline for parts ordering are set by Tronrud Engineering, based on the wanted delivery date (mid-April). The project needs the parts delivered around that time to able to conduct tests on the modules. The presentation of the design idea and the construction milestones are set by the group. They are seen as important parts to be able keep the other deadlines set by BUC and Tronrud Engineering.

If Tronrud Engineering will approve our solution at the end of iteration 2 of the elaboration phase, the group will start the first iteration of the construction phase. The second presentation will then be a “repetition” of the material presented to Tronrud Engineering earlier.

The inception phase will be done in one iteration were finished at our first milestone, the first presentation the 12th of January 2012. The time distribution for this phase is illustrated in Figure 2.

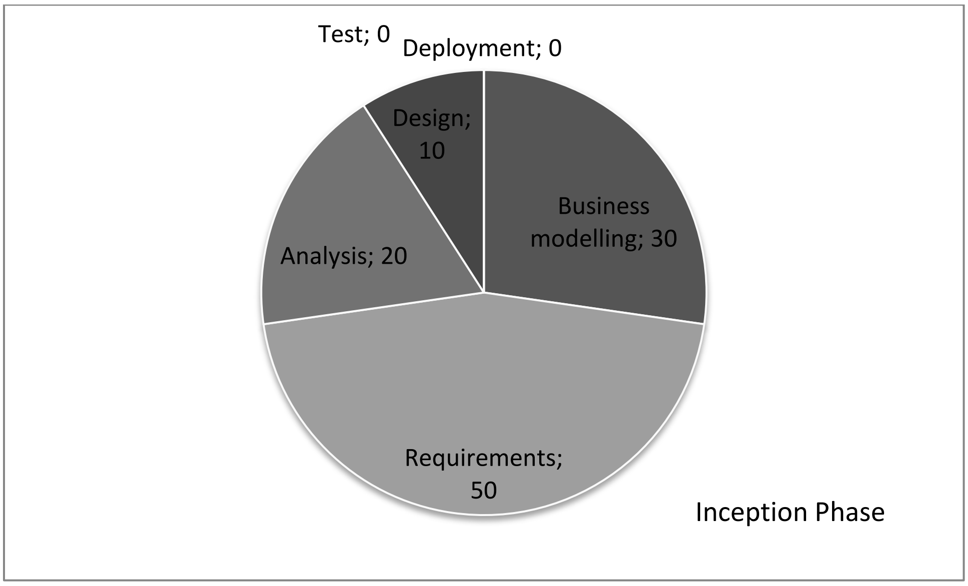

Figure 2: Inception phase time distribution

Business model:

- Determine work routines, group guidelines, project objectives, determine the project model and mapping of the project organization.
- Assigning roles to each group member.
- Signing of work contract.
- The making of templates.
- Developing a web page.
- Keep accounting of the project expenses and group member`s expenses that aren't covered by our employer.
- Make a budget that will cover the predicted expenses throughout the project.

Requirements:

- Develop first draft of the vision document.
- Determine actors and use cases for the project.
- Develop the first design diagrams.
- Mapping out the most important risks.
- Mapping out the most important non-functional and functional requirements.

Analysis:

- Develop second design/analysis diagrams.
- Renewal of the system requirements, implement them into the requirement specification.
- Updating the vision document.

Design:

- Finishing the requirement specifications.
- Developing test specifications.
- Finish all the first editions of the documentation.
- Prepare the first presentation.

FIRST ELABORATION ITERATION

This will be the first of three elaboration phases. This phase is planned to end 1.2.2012. The date is set because we feel it is necessary to share our initially ideas for a project solution. This phase will be concluded with a presentation for Tronrud Engineering of our solution idea. This is also a marked milestone as an end of this phase. This phase will not include any implementation or testing. Normally an elaboration phase will include these processes, but since this iteration has a very short time frame and is basically done the group wants to get a “no go” or a “go” to proceed with our ideas. The implementation and testing will be included in the second and third elaboration phase.

The main priorities here are to elaborate our designed use cases. The Figure 3 below shows the time distribution for the first elaboration iteration.

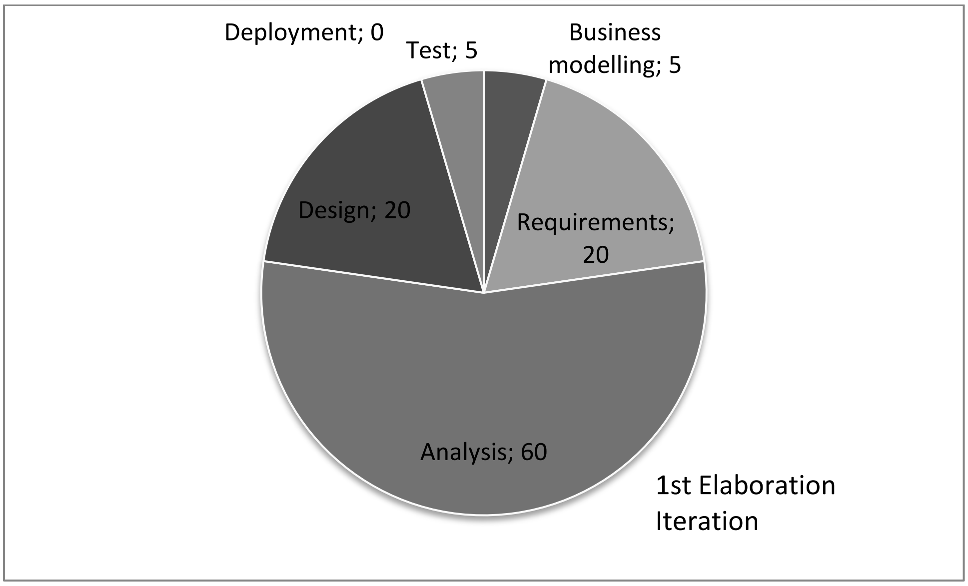

Figure 3: First elaboration iteration time distribution

Business model:

- Continuously updating our web page.
- Updating activities and Gantt.

Requirements:

- Improve "Use cases" document.
- Adding new use cases that wasn't dealt with or discovered in the inception phase.
- Discover additional risks and requirements to handle these risks.

Analysis:

- Developing the activity diagrams for each use case.
- Create a draft of an activity diagram that will create a baseline for the architecture of the whole system.
- Mapping out sensors and control unit tasks.

Design:

- Developing simple CAD drawings for the ideas to the design of the system.

After the presentation of the solution ideas, Tronrud Engineering will either give us a go or not for our design idea. If the design is acceptable, we will continue developing the designs and testing of the designs in this phase.

The second elaboration iteration is planned to end with a presentation at Tronrud Engineering, 1.3.2012. If this presentation is a success, the third elaboration phase will be dropped. The third elaboration were dropped. Our solutions needed more work, and therefore the second and third elaboration were merged. The iteration milestone was our second presentation the 16th of March.

The Figure 4 shows the time distribution for the second elaboration iteration.

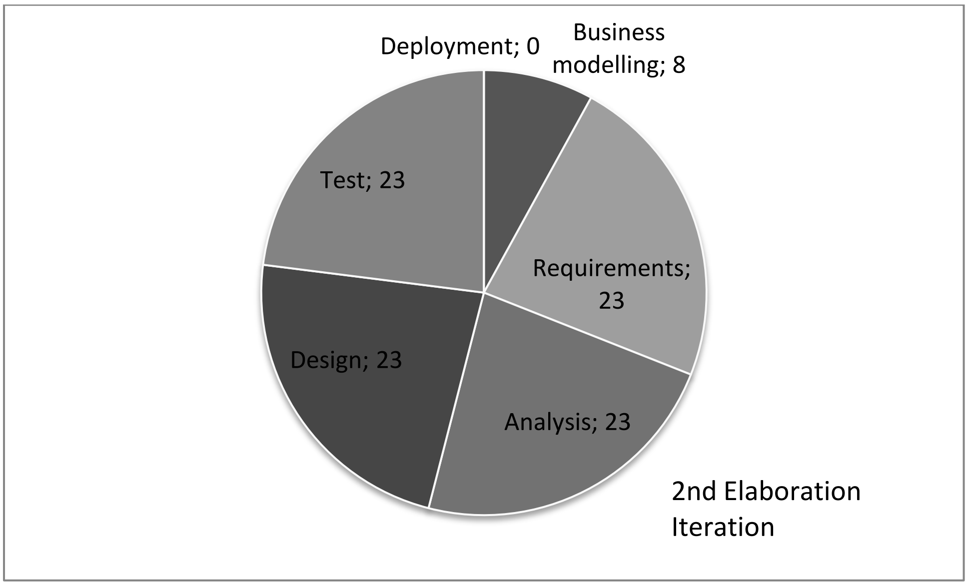

Figure 4: Second elaboration iteration time distribution

Business model:

- Continuously updating our web page.
- Adding building costs to our budget.
- Updating activities and Gantt.

Requirements:

- Develop activity diagrams that integrate the use cases into a single system.
- Mapping out alternative flows.

- Evaluate the design diagrams.
- Evaluate the requirements.
- Making more defined/documented decision in regards to requirements that deal with quality and durability.

Analysis:

- Evaluate activity diagrams for the use cases.
- Activity diagrams for modules.
- Evaluate the needs for sensors in the system.
- Evaluating sensor solutions for our systems.
- Evaluating choice of microcontroller.

Design/Implementation:

- Continue working on the CAD drawings.
- Start making assembly drawings.
- Design the circuit drawings for the system.
- Design the microcontroller/control unit. That means making the PCB drawings.

Test:

- Evaluation tests in SolidWorks. This is to control the physical size and material strength according to design.
- Testing voltages, currents and calculating simulated results from simulated circuits in Multisim.

FIRST CONSTRUCTION ITERATION

After the second presentation we plan to have the order of the parts delivered, so we can start the construction phase after the second presentation and the actual construction when the parts arrive. The main goal of this iteration is to construct all modules and test them individually.

The first construction iteration is planned to end when all the individual modules are built and tested, 20.04.2012. The time distribution for the first construction iteration is illustrated in Figure 5. Our parts wasn't delivered and tested in this iteration, and its end date was set to 27.04.2012. The final parts were set into production right after the Easter holidays (early in April) and we believe this will arrive during the second construction iteration.

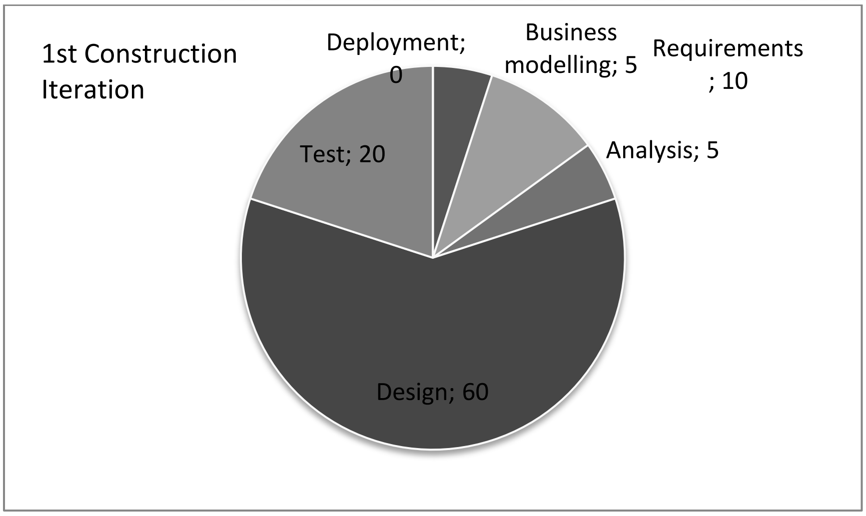

Figure 5: First construction iteration time distribution

Business model:

- Continuously updating our web page.
- Adding undiscovered building costs to our budget or reduce the budget if it’s too large.
- Adding costs to our financials.
- Updating activities and Gantt.

Requirements:

- Create use cases that capture the remaining functional requirements.
- Adding or removing requirements according to test result done in the third elaboration phase.

Analysis:

- Implementing discovered use cases into the analyze model diagrams.

Design:

- Adding discovered changes to work drawings and software.
- Complete 2D drawings

Implementation:

- Integrating software and sensors for each module.
- Order all electrical hardware
- Order all parts that has to be produced

Tests:

- Perform tests on each module as fast as these arrives.

SECOND CONSTRUCTION ITERATION

The main goal of this iteration is to assemble the whole system using the parts we have constructed and tested in the first iteration. When the system is assembled we can perform tests that are designed to test the whole system. We can also perform white box testing.

The parts didn't arrive during the first construction iteration, so this iteration has to include construction, individually tests and full system tests. The white box testing have been moved to the first transition iteration.

The second construction iteration is planned to end when the whole system is built and tested and we have delivered all of the documentation 29.5.2012. Figure 6 illustrates the time distribution for the Second construction iteration.

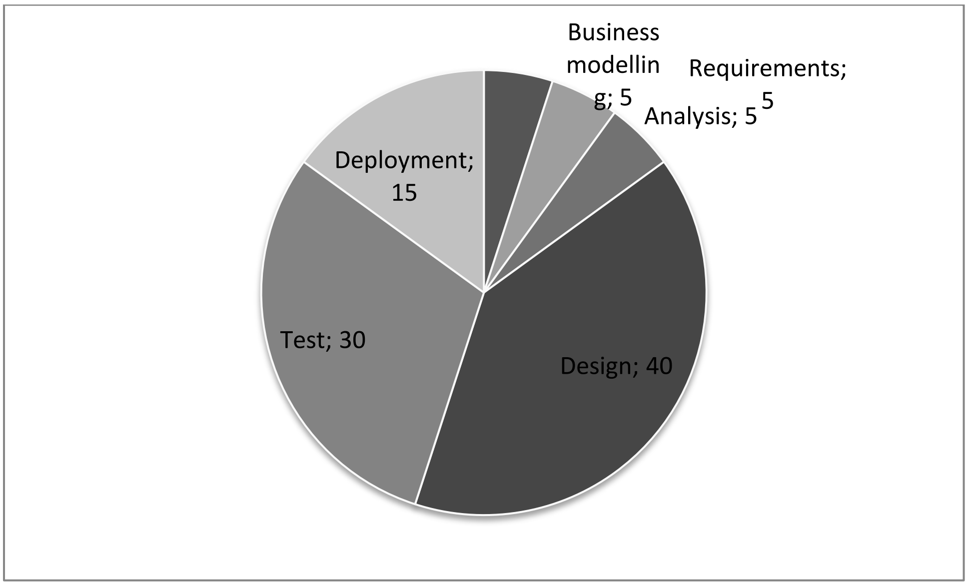

Figure 6: Second construction iteration time distribution

Business model:

- Continuously updating our web page.
- Adding undiscovered building costs to our budget or reduce the budget if it's too large.
- Adding costs to our financials.

- Updating activities and Gantt.
- Produce a poster.

Requirements:

- Create use cases that capture the remaining functional requirements.
- Adding or removing requirements according to test results done in the third elaboration phase.

Analysis:

- Implementing discovered use cases into the analyze model.

Design:

- Adding discovered changes to work drawings and software.

Implementation:

- Integrating software and sensors for the whole system.
- Start assembly of modules.
- Start assembly of the whole system.

Test:

- Perform integration and full system tests

FIRST TRANSISTION ITERATION

This iteration has been moved to after the 29.5.2012. The iteration will start 29.5.2012 and end at our final presentation 13.06.2012. This iteration will be used to final testing's and improvements of the prototype. It will also be used to prepare the final presentation. We hope to conduct some black box testing, but the main focus will be to have a fully functional prototype. The group wants to develop a small document, that summarizes the prototype results. The document will contain a conclusion of what solutions we have developed that could work and what kind of modifications these need.

Document developed in this iteration:

Prototype summary (D-00.B.38-EM)

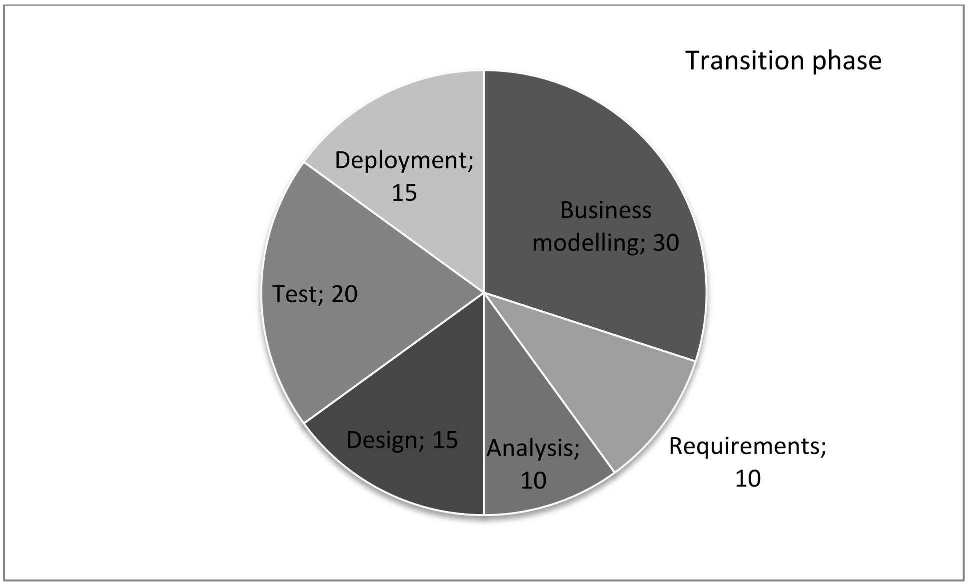

Figure 7: Transition phase time distribution

Business model:

- Prepare the third presentation.

Requirements:

- -If we any tests results in a requirement is met, this will be mentioned in the document.

Design:

- Make physical changes on the prototype.

Test:

- Perform full system test while the prototype is being modified. The prototype can be improve by increasing its performance and durability.

TOTAL PLANNED AND SPENTD TIME

This project is planned to June. The plan (Gantt) is divided into days. Towards Easter, we don’t have full working weeks, this has been taken into consideration.

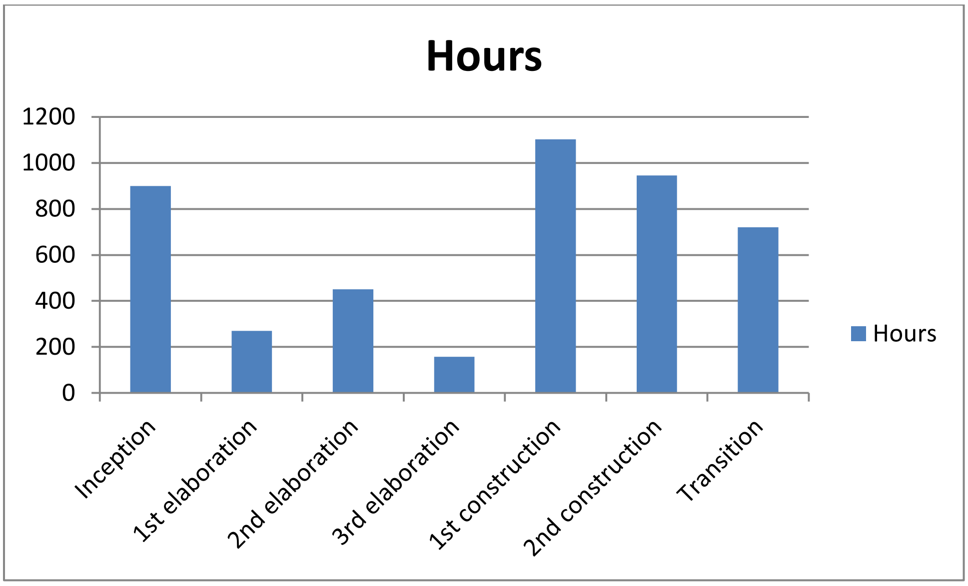

Figure 8: Total hours for the project

In the Figure 8 above, the different iterations have been planned into hours. This gives a better overview of the sizes of the iterations. The total planned hour-use of this project is 4545 hours.

Specific work hours spent on activities and by each group members, can be found in the Work hours folder.

Total work hours spent in this project:

Inception phase:	First elaboration:	Second elaboration:	First construction:	Second construction:	Total:
1046,50	391,45	1137,15	454,75	931,80	3961,65

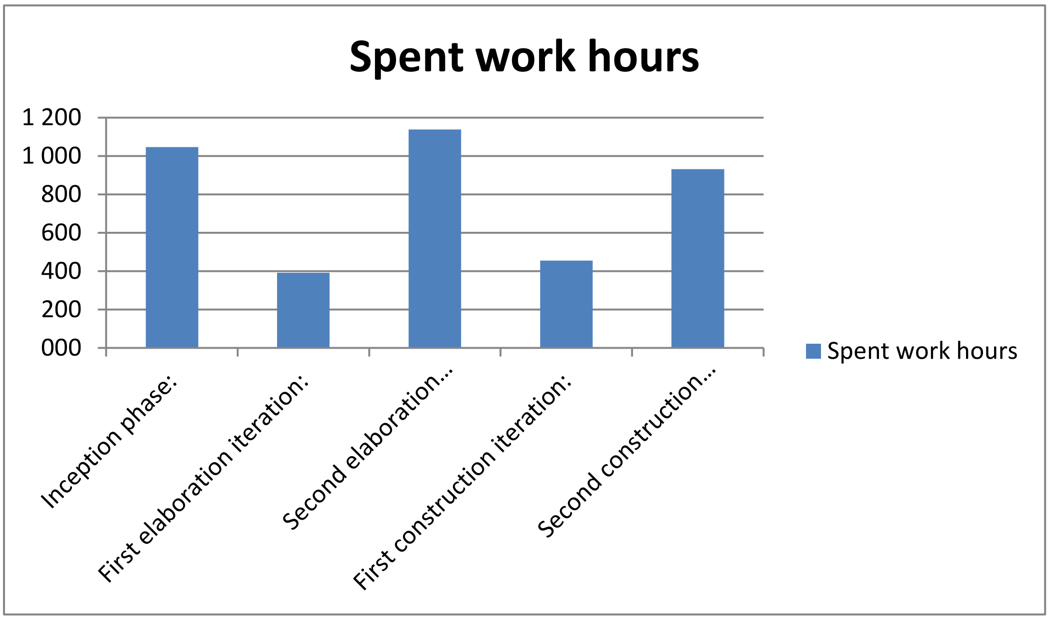

Figure 9: Diagram of spent work hours

If you compare Figure 8 and Figure 9 you'll find deviations and changes:

- **Third elaboration iteration and transition phase is removed:**
  The third elaboration iteration was removed because many of the second elaboration goals weren't completed. The group wasn't able to produce approved design solutions in time. In order to improve the design the iteration was extended and the third was cancelled.
- **Most of the work hours are located in elaboration phase, not in construction and transition phase:**

The amount of work hours spent on elaboration and construction are equal. This is the result of the group struggling to find good design results. The second elaboration iteration milestone was moved ahead one week.

Because the group couldn't complete designs in time or reduce the demands sooner, the elaboration took more time than planned. This again, resulted in cancellation of the transition and less available time for construction.

GROUP GUIDELINES

MEETINGS:

- There will be a minimum of 1 meeting per week which all of the group members will attend.
- There will be a minimum of 1 meeting per week with the group internal adviser. This will be from January the 1st.
- Meetings for the group only, shall have a written notice sent to all meeting participants within 48 hours after the meeting. These 48 hours can only consist of workdays.
- If external advisers or customers are to attend a schedule meeting, the group leader has to inform and confirm this at least 2 weeks in advance.
- If internal advisor is to attend a scheduled meeting, the group leader has to inform and confirm this at least 6 days in advance.
- The leader of the meeting will have the responsibility to write meeting notices and appoint the meeting secretary.
- The secretary have to complete and send the meetings summary to the group leader, and make it available for the group leader, within 24 hours after the meeting.
- Documentation has to be available for the advisors at least 48 hours before the meeting.
- As long as the meeting participants consist of group members, the person who is leader and secretary will be changed from meeting to meeting. The person who was secretary will be leader at the next meeting.

DOCUMENTATION AND STORAGE

- All digital written materials will be saved in a folder called "Bachloroppgave" on Dropbox. The advisors will be given access to a separate folder called “ASCS”. The IT manager will make sure one backup is made once every day.
- Files and file projects that are too big to be stored on Dropbox will be saved on the group members computers, each group member have their own responsibility to make backups of their work. Examples of files that are too big are 3D design files such as SolidWorks projects.
- IT manager have to supervise files stored on Dropbox.
- Each member has their own subfolder marked with their name. Here they can store their own work.
- The group will create a webpage about the progression and challenges through the project. We will use ASCS as a pseudonym for the TC2 because Tronrud Engineering AS don’t want any too much information about the TC2 or a potential extra module to be published online. The web address is: http://www.project-ascs.tk
- All decisions should be documented and distributed to the members.
- We will be using EndNote to keep track on the sources we are getting information, data, pictures and tables from. The Dropbox folder contains a folder named “EndNote”, and when all the members of the group are using this folder for sources, it will always be synchronized.

COMMON EXPENSES

- Keeping track of common expenses is Economics manager responsibility.
- Trips made to Tronrud Engineering in Hønefoss will be done with group members’ own cars. At the end of this project the travel expenses will be divided fairly among the group members.
- Coffee, cakes, food and other accessories.

COMMUNICATION WITH ADVISER, CUSTOMERS AND PROJECT LEADER

- The project structure illustrates how communications between project members will be.
- To minimize misunderstandings and communication problems, external and internal advisers will only have to contact the group leader when communicating by email. It is then the group leader's responsibility to distribute these to the right persons in the group.

LOGGING OF WORK HOURS

All the time spent on the project will be logged by each individual person on the group. The hours should be logged like this:

- As soon as a person is finished working on one specific activity, he should write down how long time is spent on that activity before he continues with the next activity.
- All kinds of breaks should not be included. From the second construction iteration a normal work day is considered as 7,5 hours (that's 8 hours minus the lunch break). A working week will then include 37,5 hours in average.

ATTACHMENTS

1. Gantt plan with plans for each iteration

1. Vestby, V. *TC-1 HISTORY*. 28/12/2011; Available from: http://dwn-tc2.blogspot.com/p/tc-1-history.html.

2. Engineering, T. *About the TC-2 development project*. 28/12/2011; Available from: http://dwn-tc2.blogspot.com/p/tc-2-project.html.

3. Engineering, T. *About us*. 09/10/2011; Available from: http://www.tronrud.no/index.php?id=3&L=1.

4. Engineering, T. *Vision*. 09/10/2011; Available from: http://www.tronrud.no/index.php?id=25&L=1.

5. Engineering, T. *Our values*. 09/10/2011; Available from: http://www.tronrud.no/index.php?id=26&L=1.

6. Wikipedia. *IBM Rational Unified Process*. 28/12/2011; Available from: http://en.wikipedia.org/wiki/IBM_Rational_Unified_Process.

7. Wikipedia. *Software development process*. 28/12/2011; Available from: http://en.wikipedia.org/wiki/Software_development_process#Software_development_models.

TERM LIST FOR THE LOOM AND TC2 FOR THE“AUTOMATIC SHUTTLE CONTROL SYSTEM”

D-07.A.06-A

Release 3.0

RELEASE NOTES

Date	Version	Description	Author
29.11.2011	1.0	Final edit	Andreas Stustad
19.12.2011	1.1	Edited “The loom”	Andreas Stustad
28.12.2011	1.2	Added explanation of TC2	Andreas Stustad
28.12.2011	1.3	Added chapter “TC2”	Mats Strand Sætervik
03.01.2012	1.3.1	Changed document filename	Andreas Stustad
06.01.2012	1.3.2	Standardized the front page and TOC. Updated the TOC and FOC.	Eirik Nordstrand
09.01.2012	2.0	Finishing document	Eirik Nordstrand
16.01.2012	2.0.1	Added to term list	Inge Ytre-Eide
27.01.2012	2.0.2	Added "Garage" and "Thread tray" Fixed spelling and grammar	Eirik Nordstrand
08.03.2012	2.0.3	Added BLDC, DAC and MOSFET to explanations	Inge Ytre-Eide
15.05.2012	2.1	Grammar and spelling, updated text	Andreas Stustad
25.05.2012	3.0	Finalized document	Andreas Stustad

ABOUT THIS DOCUMENT

This document will give the reader some basic knowledge about a traditional loom and the loom made by Tronrud Engineering, the Thread Controller 2. This document can be used as a reference document while you are reading the other documents. We have created this document because the terms of a loom no longer can be said to be general knowledge.

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INTRODUCTION

This document contains general information about the loom and the Thread controller 2, as well as relevant foreign words used in other documents. Pictures are used for better explanation on each subject.

TERM LIST

ABBREVIATIONS

TC1 – Thread controller 1

TC2 – Thread controller 2

THE BASIC LOOM

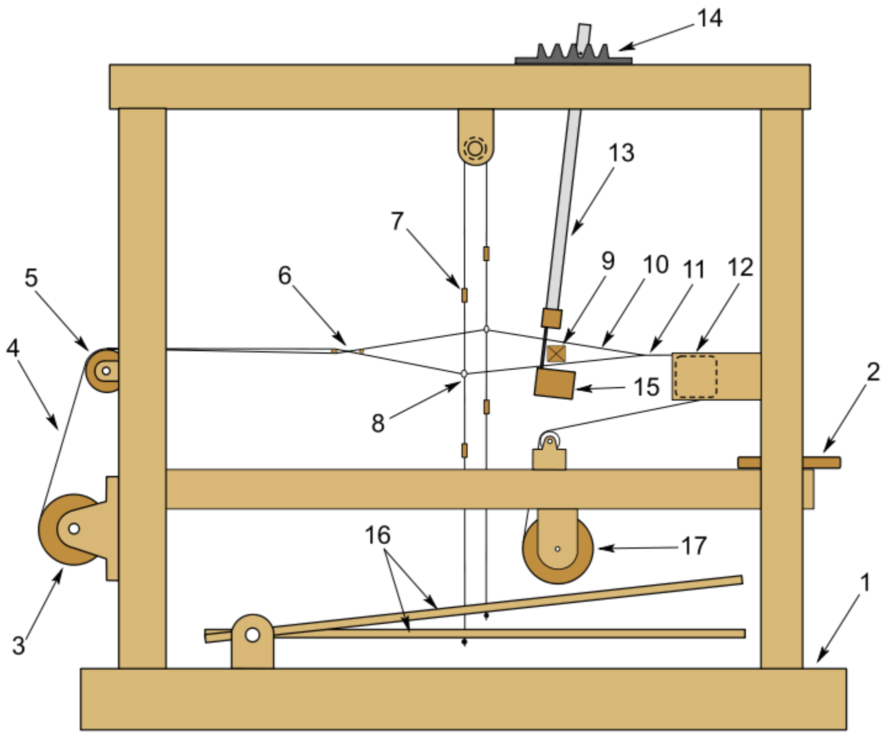

Figure1: An ordinary foot operated loom [2]

1. Frame
2. Seat for weaver (not significant here)
3. Warp beam or let-off roll
4. Warp threads
5. Back beam
6. Rods
7. Harness
8. Heddle
9. Shuttle with weft yarn
10. Shed
11. Completed fabric
12. Breast beam
13. Beater with reed comb
14. Beater adjustment (not significant here)
15. Lathe (not significant here)
16. Treadles (not significant here)
17. Take-up roll

Figure 1 shows how a foot operated loom is built up. The TC1 and the TC2 is a little different in automation of the heddles, different mounting of the beater and so on, but the basic principles are the same. Figure 2 and Figure 3 show how early versions of the TC2 loom are built up.

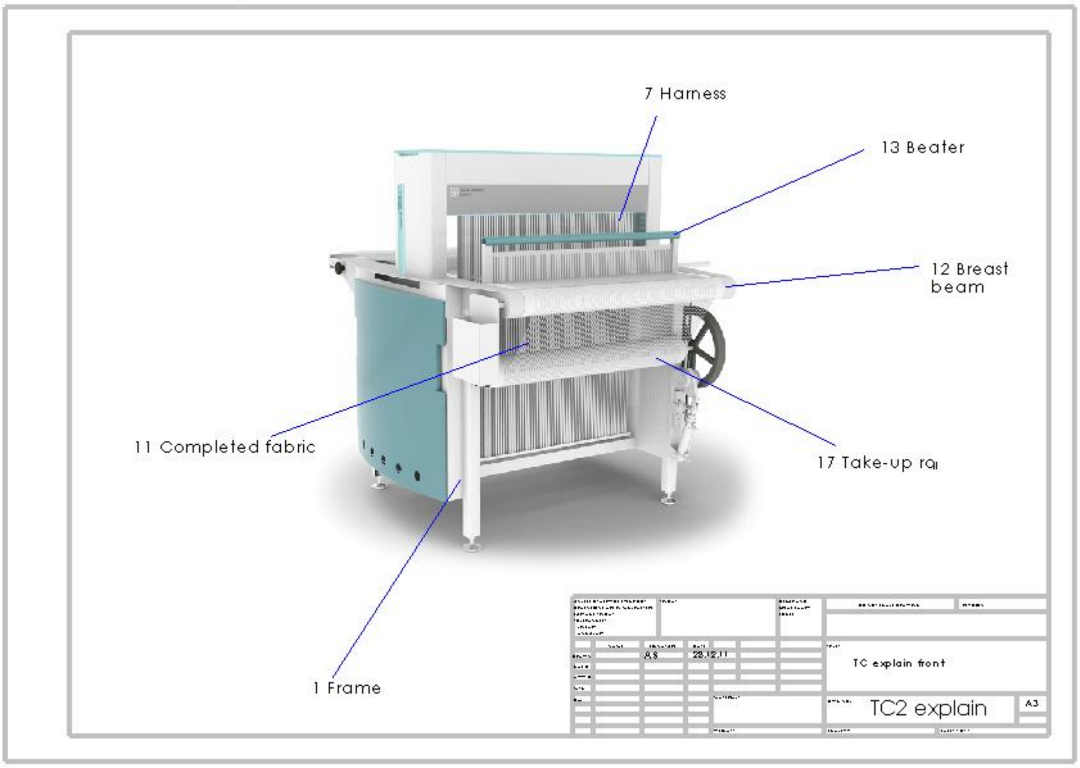

Figure 2: TC2 front [1]

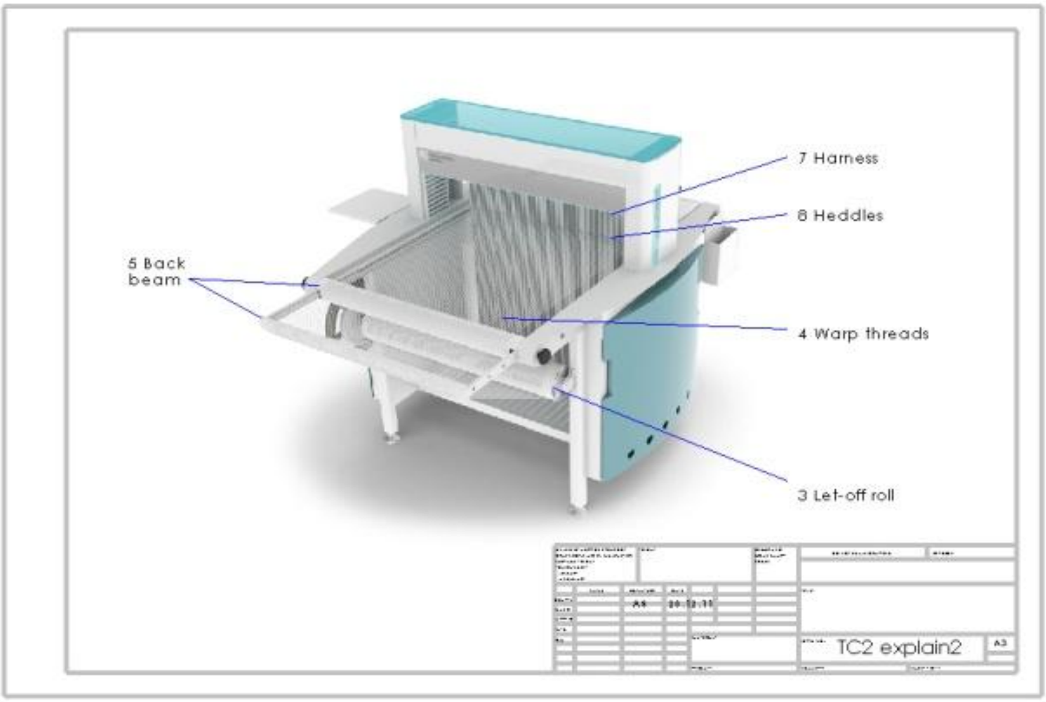

Figure 3: TC2 back [1]

A loom is a device used to weave cloth or fabric. The major components of a loom are the warp beam, heddles, harnesses, shuttle, reed and take-up roll.

An ordinary loom works briefly like this:

At first, longitudinal warp threads are hooked up from the warp beam, through the heddles and the reed and then on to the take-up roll. In operation, the warp threads are drawn from the warp beam by the take-up roll. The heddles, which are controlled or raised by the harness controls, raise selected parts of the warp threads, according to the requested design. This makes a shed, or space, in the area between the beater and the complete fabric. It is in the shed that a shuttle is sent through, leaving a weft thread between the warp threads. The shuttle has a small spool with weft yarn, and is formed like a spaceship making it easier to throw it between the warp threads in the shed. The newly laid weft thread is beaten into the complete fabric by a beater. The beater has a reed or comb that the warp treads are placed into. Now, the take-up roll is spun a couple of degrees, and the process restarts.

EXPLANATIONS OF RELEVANT WORDS:

Advisor (external): *The external advisors will help us with the specific problems we will encounter on our product. They have specialized knowledge about the product we will be designing, and can help us with technical problems around this.*

Advisor (internal): *A person hired on Buskerud University Collage. This person will help us with the general problems we will encounter as a group. The internal advisor will also point us in the correct direction if we get stuck somewhere.*

Beater (13): *An object the weaver uses to push the newly woven thread in to the rest of the threads of the complete fabric.*

Black box testing: *Testing performed by a person without any knowledge of the systems inner workings. The person just needs knowledge about how to operate the system.*

BLDC motor: *A brushless direct current motor, with a static core.*

Blocks: *Blocks which holds several harness wires. These blocks are controlled by computer signals and vacuum to move the harness and therefore the heddles to lift the warp.*

Breast beam (12): *The beam that guide the completed fabric to the take-up roll. The weaver uses to rest her/his hands to this beam. On the TC 2, this beam is fixed to the part of the frame that the beater slides on. This is also the part of the frame that our module will rest on.*

Control unit: *Hardware that controls and monitors the entire system.*

Customer: *The person who wants to buy our finished product*

Cutter: *System that cuts the thread.*

DAC: *(digital to analogue converter) an electronic device that converts digital signals to analogue signals.*

Dropbox: *Software used internal between the group members to keep our computer files synchronized with each other.*

EMC: *EMC is known as Electro Magnetic Compatibility. I.e. how different electronic devices/circuits tolerate each other. How an electronic device handles incoming EMI from an external or internal source.*

EMI: *EMI is known as Electro Magnetic Interference, that is a disturbance generated in an object, can be either natural or artificial. The disturbance is transmitted through waves and can in worst-case result in circuit failure.*

Group leader: *A person from the project group who is responsible for the group. This person was voted by the group to be the leader. If the group can't agree in a conflict, the group leader will have the last word internal in the group. The group leader will also be the person who is communicating with the project leader, and he is always the meeting leader when we have meetings that consist of other than the group members.*

Employer: *The employer is the company that our project group is working for. In this project, the employer is Tronrud Engineering AS.*

Fabric (11): *The finished woven textile.*

Feeding mechanism for shuttle arm: *Mechanism that feeds the gripper arm which includes: electrical motor, wheels, gears and motor control.*

Garage: *The casing on the left and the right side of the warps, where the shuttle has its turning point.*

Grade result: *The Norwegian grade-system has "A" as the best result, and "E" as the worst result. The grade "F" implements that the person has failed the course.*

Harness (7): *The wires/threads which are controlled by the blocks, and have heddles in the ends.*

Heddles (8): *The eye in the end of the harness which the warp threads go through.*

Loom: *The whole system that the weaver is using to weave fabric.*

Meeting leader: *The meeting leader is the person who is responsible to convene meetings, and keep track of the agenda. The meeting leader does also have to appoint the writer for the meeting.*

Module: *The different parts of the product.*

MOSFET: *(Metal oxide semiconductor field effect transistor) a transistor that is voltage based.*

Multisim: *Multisim is a simulation program for designing electric circuits. Build and run circuits. More information can be found at http://www.ni.com/multisim/*

PCB: *"printed circuit board", the board under the circuit which works both as support and contains the wiring between the different parts. The wires are "cobber roads"*

Pick: *The weft thread that is left behind the shuttle, between the warp threads.*

Pre-study: *The pre-study is the first part of a project like this. In this part, one is documenting a lot of information, and makes the necessary preparations before we can start with the prototype.*

Product: *The whole system, we are developing.*

Project group: *The group of people who will be planning and implement the product. The project group does not include advisors, the project leader or the customer.*

Project leader: *The person who has hired us, and will always have the final word in a discussion*

Project model: *A project model is a model that describes the different cycles of a product development.*

Prototype: *An early model of the final product. The purpose of a prototype is to present and test the product, and prove that the product is working.*

Reed: *The comb inside the beater, which all warp threads are leaded through.*

Requirement specification: *This covers what requirements we set for our product*

RUP: *Rational Unified Process, a project model based of UP by IBM*

Secretary: *See "writer".*

Shed (10): *The space between the warps, between the beater and the complete fabric.*

Shuttle (9): *The object that the weaver sends through the shed. It holds a spool of weft yarn.*

Solid works: *A 3D CAD-program for designing and simulating a mechanical system.*

Spool: *The spool where the unwoven thread is housed.*

TC1: *An acronym of "Thread Controller 1". This was the first of looms by Tronrud Engineering.*

TC2: *An acronym of "Thread Controller 2". This is the new loom that Tronrud Engineering are working on now.*

Test specification: *This consists of the test we will be doing for the system and cross-check this with the requirements.*

Thread: *The weft thread in which is used to weave.*

Thread feeding system: *Stores the thread from the spools till the thread selection system.*

Thread holding system: *System that stores all eight spools and also spool sensors.*

Thread selection system: *The system that will change between different threads/colours.*

Thread tray: *A path of thread, systemised so they will not interfere with each other.*

UP: *Unified process, a project model that's based on iterations*

Warp (4): *The longitudinal threads.*

White box testing: *White box testing is testing performed by a person with good knowledge of the system. The tester may generate input data to provoke bugs in the system.*

Writer: *The person who takes notes of the meetings, and writes a summary of the meeting when it's done. The writer will be the group leader at the next meeting.*

THE TC2

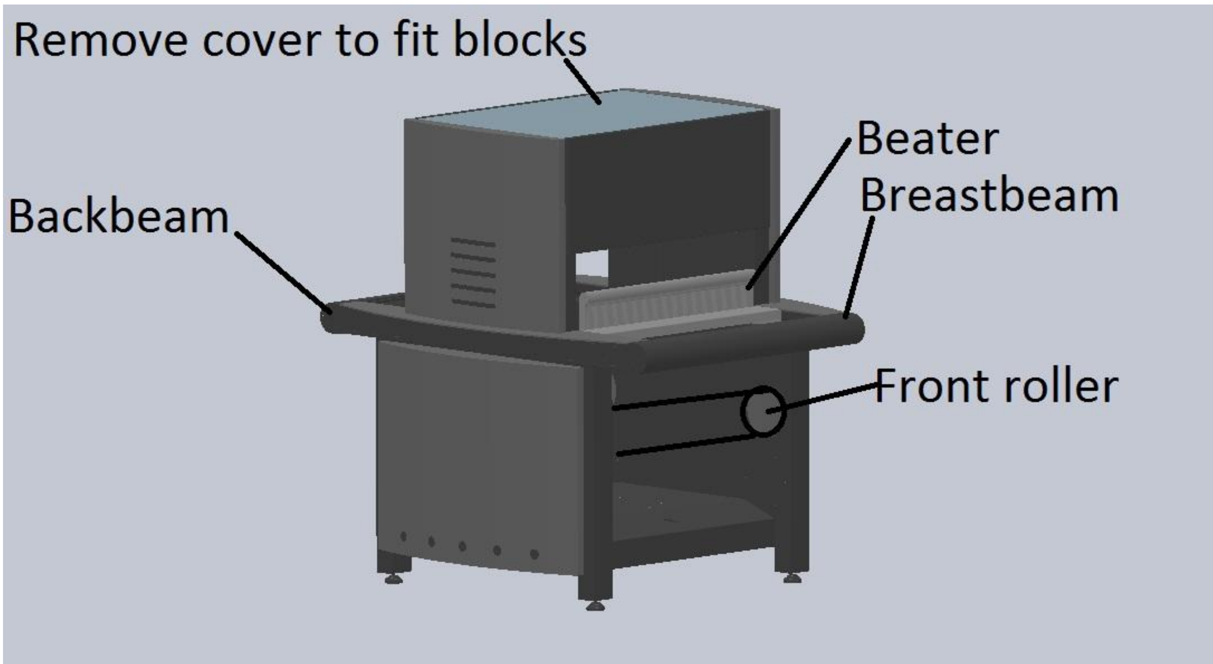

Figure 4: CAD drawing of the TC2

Figure 4 shows a CAD drawing of the TC2. In this picture it is not ready to weave, its missing threads and blocks. The rollers will adjust the warp threads so that the woven fabric is moved away from the weavers working space. It will also keep the warp threads at the proper tension. The rollers are moved by two electro motors which are controlled by TC2's motherboard.

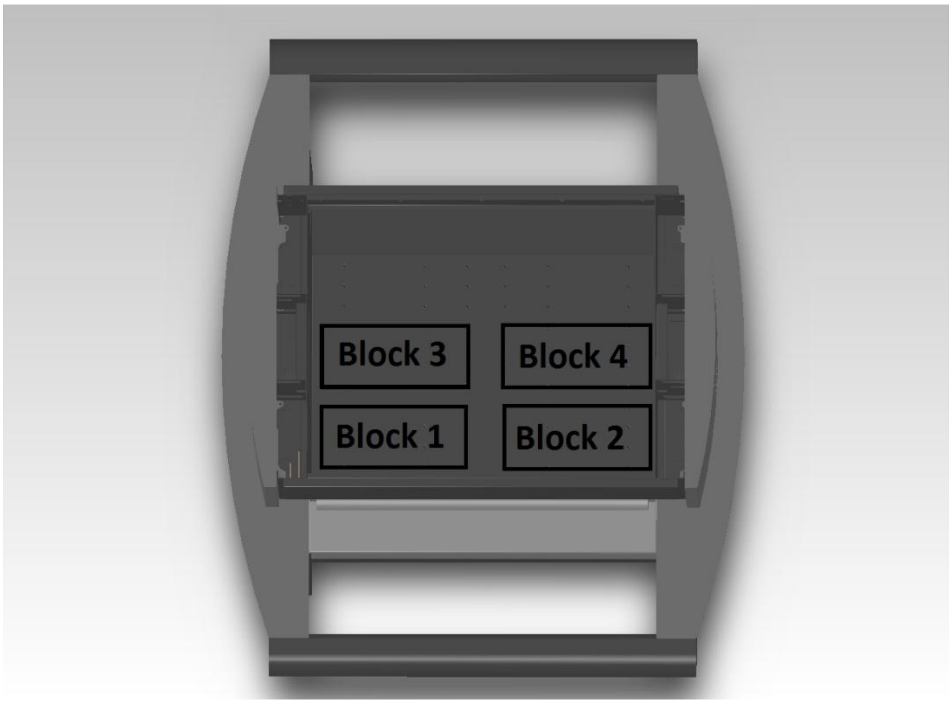

Figure 5: The TC2 viewed from above

Figure 5 illustrates how the blocks can be installed.

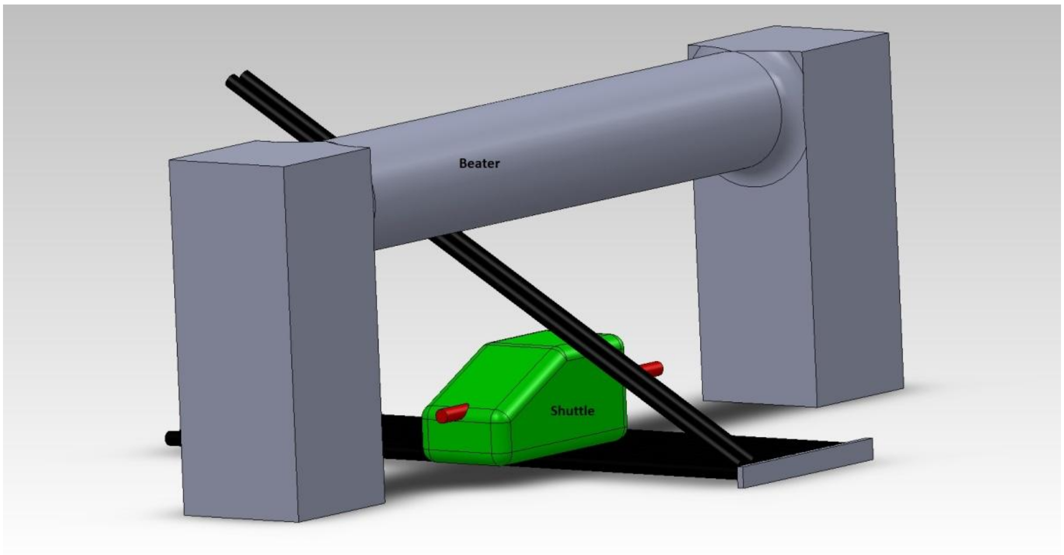

Figure 6: Illustration of the shed

Figure 6 is a simple illustration of the shuttle moving through the shed. The shed is the gap between the two warp threads. The reed is not illustrated in this picture. As illustrated in the Figure 6, some of the threads are being lifted by the block. Which thread is being lifted is decided in the software program and by the preset pattern desired by the weaver. Inductors lift some of the heddles by applying vacuum to them.

Figure 7: An ordinary shuttle [3]

Figure 7 shows an ordinary shuttle. Normally, with non-industrial looms, the spool is stored within the shuttle. If the weaver uses different colors he or she usually uses several shuttles.

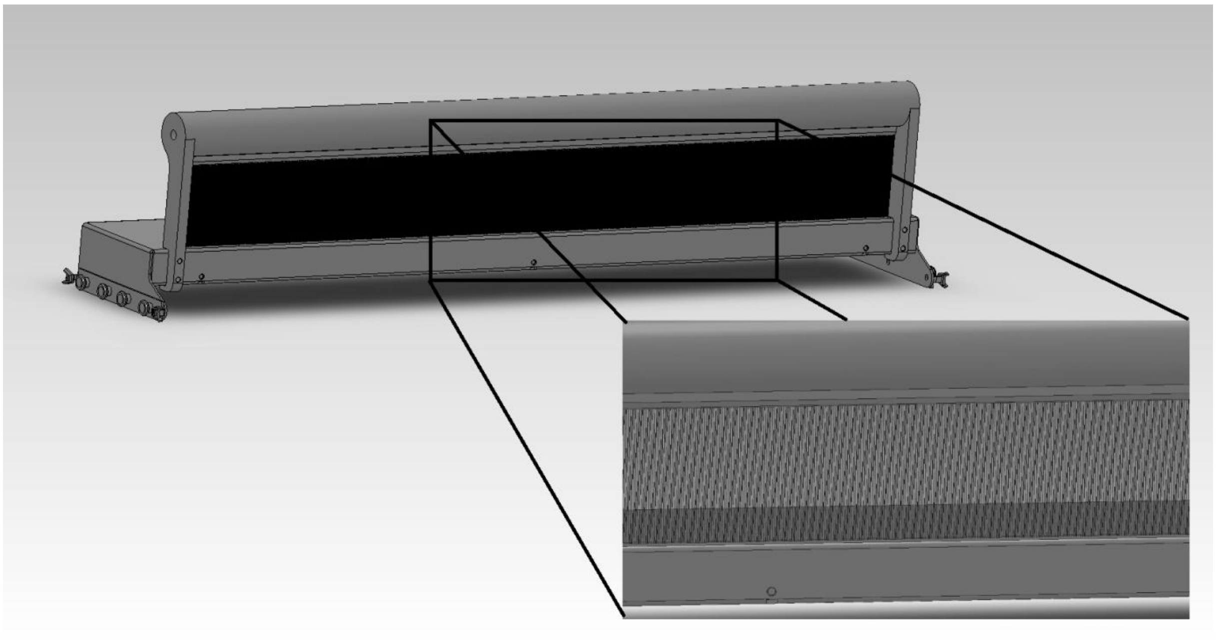

Figure 8: The beater, with enlargement of the reed

Figure 8 shows the beater on the TC2, the enlargement shows the reed. All of the warp threads pass through the reed. The reed works like a comb, keeping all of the warp threads in line and presses woven thread against the woven fabric.

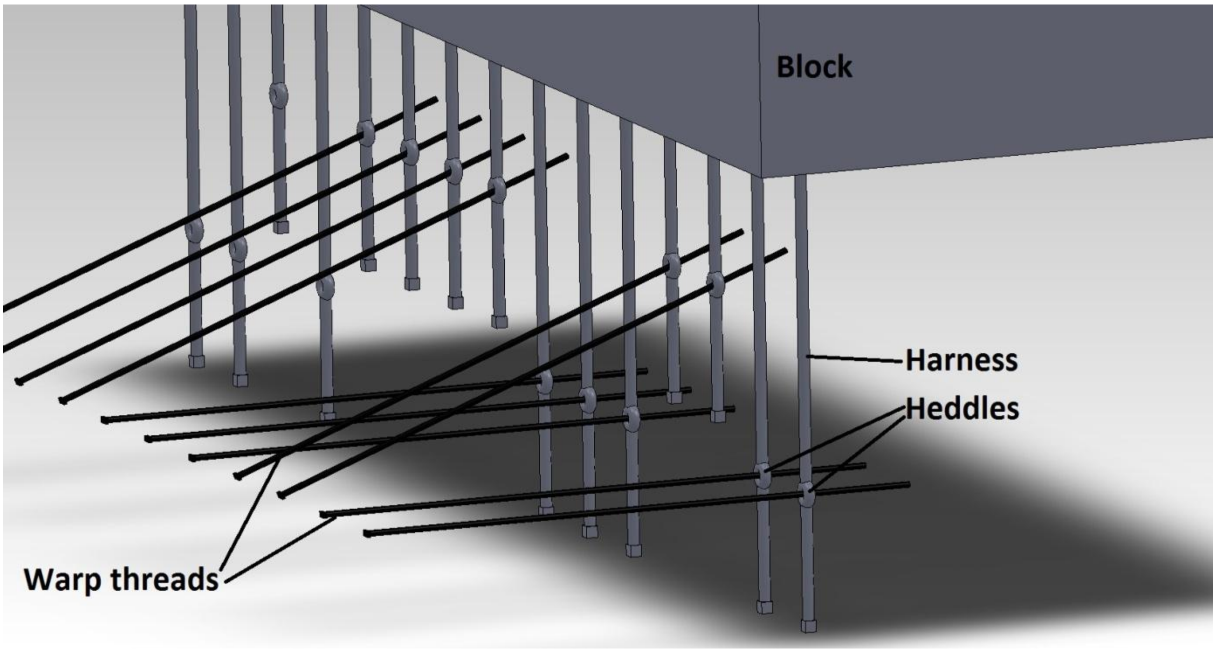

Figure 9: Illustration of the block lift

Figure 9 illustrate the lift done by one block on the TC2. The illustration shows only the first row of harnesses.

SOURCES

1. 360grader. *Prosjekter: TC-2*. 29/12/2011; Available from: http://www.360grader.no/prosjekt.asp?m=7394&s=&did=129.

2. Wikipedia. *Loom*. 29/11/2011; Available from: http://en.wikipedia.org/wiki/Loom.

3. Unknown. *Weaving Shuttle*. 29/12/2011; Available from: http://1.bp.blogspot.com/_1jD2dB6lg1A/S0Fsoq0ncTI/AAAAAAAAANQ/Ozl6XgS9sBI/s1600-h/charkhaweavingshuttle122809b.JPG.

DESIGN AND ANALYSIS OF "AUTOMATIC SHUTTLE CONTROL SYSTEM"

D-00.A.18-EM

Release 2.0

TRONRUD ENGINEERING AS

RELEASE NOTES

Date	Version	Description	Author
02.02.2012	0.1	- First draft	Eirik Nordstrand
02.02.2012	0.11	- Edited spacing	Mats Strand Sætervik
06.02.2012	0.2	Added text to chapter about spools, module 23	Andreas Stustad
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08.02.2012	0.4	Added parts for the sensor	Eirik Nordstrand
09.02.2012	0.5	Removed discarded solutions	Eirik Nordstrand
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27.02.2012	0.6.4	Added figure and edited chapter 23	Andreas Stustad
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08.03.2012	0.7.1	Added Prototype to module 20	Andreas Vander
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08.03.2012	0.7.4	Added for Gripper, Gripper arm and Feeding mechanism for gripper arm	Vazgen Karlsen
12.03.2012	0.8	Added overview	Eirik Nordstrand
13.03.2012	0.9	Added feeding mechanism gripper arm	Mats Strand Sætervik
14.03.2012	1.0	Finalized document	Eirik Nordstrand
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02.05.2012	1.2.1	Updated module 20	Andreas Vander
03.05.2012	1.2.2	Updated figures	Andreas Stustad
07.05.2012	1.2.3	Updated chapter 40 and 23/22	Andreas Stustad
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15.05.2012	1.3.1	Fixed markings done by EN (updated text) Added module 14	Andreas Stustad Andreas Vander Mats Strand Sætervik
16.05.2012	1.3.2	Added module 30, serial communication	Inge Ytre-Eide
18.05.2012	1.4	-Added information about module 30	Mats Strand Sætervik

21.05.2012	1.4.1	Proofreading	Inge Ytre-Eide Andreas Stustad
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24.05.2012	1.5.1	Edited text module 23, 22 and 40 Edited intro	Andreas Stustad
26.05.2012	1.5.2	Added information on module 30 and 12	Mats Strand Sætervik
28.05.2012	1.5.3	Edited information about module 10, 11 and 12 Added fig 27 and text	Vazgen Karlsen Inge Ytre-Eide
29.05.2012	2.0	Finalized document	Eirik Nordstrand

ABOUT THIS DOCUMENT

This document contains our current research for the different modules at the loom. It describes the solution, and discussing advantages and disadvantages for the current solution. This document will be continuously updated.

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INTRODUCTION

This document represents our design as well as our analysis for the solution we use on the prototype module. Solutions that have been discarded for various reasons are listed in the document "Discarded design and analysis" (D-00.B.23-EM). The next chapters go into the design and analysis on each module or sub-system. Here are problems and solutions listed, as well as explanations and pictures of the development during the project. Some modules have been ordered and tested as plan B solutions. This is because of prize and the fact that we needed parts fast to make our prototype. It can be mentioned that even though our solutions say one thing, the prototype do not necessary use the exact same solution, but a modified one for prototype use. This will be explained in the chapters below.We are building a plug-and-play module that will be mounted on the loom TC2, illustrated in Figure 1. Our product can be divided into three main parts: The thread/spool holding- and feeding system (1), the thread selection module (2) and the Gripper/gripper arm feeding modules (3). The eight different threads are mounted on the thread/spool holding system. From there, the thread will be thread down through the feeding system to the thread selection module where the correct thread will be selected for the current pick. Then, the gripper will go from (3) to (2), and grip the correct thread, and pull the thread double, back towards to (3). Halfway back, the thread selection system will release the end of the thread, and it will then be laid as a single thread. The thread will then be cut at (2) before the weaver must manually use the beater to press this single thread towards the rest of the threads. The gripper will now go on and grabs the next pick.

Figure 1: TC2

This document will show the design of our module or prototype, which with an overview looks like the picture in Figure 2.

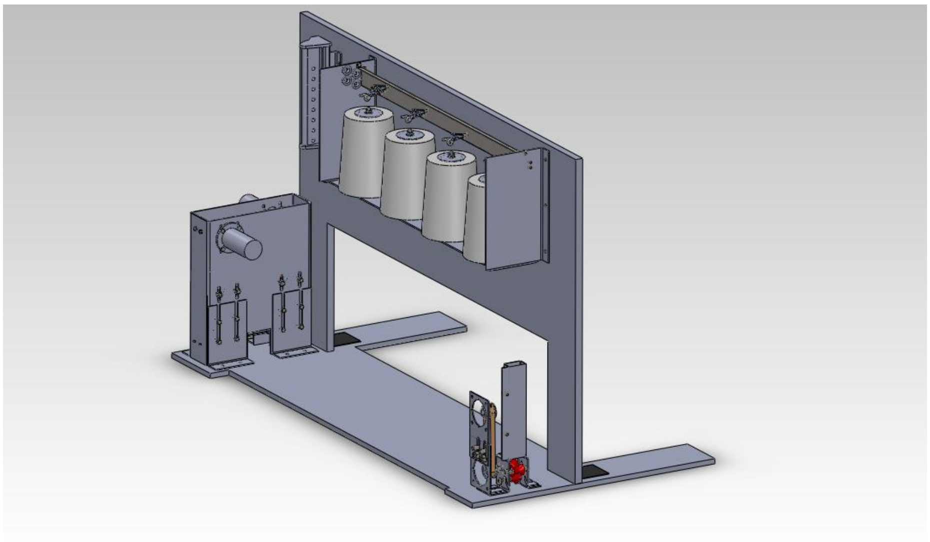

Figure 2: Automated Shuttle Control System overview

As stated above, the system is divided into 3 main parts:

- Thread holding and feeding system, shown on the top with 4 spools. This is connected with a thread sensor for sensing moving threads. The original design included 8 spools on 2 rows, but just one row was made for prototyping. Threads go from the spools up into “hooks” that leads them to the thread sensor and thereafter to thread selection.
- Thread selection, shown furthest back, readies the selected thread for pickup. The original design includes two modules with four arms in each. Due cost and complexity, the prototype was downgraded to one module with two arms. The selected thread gets tensioned between a moving overhead arm and a holder so the gripper can easily grip it.
- Gripper/gripper arm feeding mechanism, shown closest, contains the gripper arm feeding mechanism and the arm with gripper. The arm feeding mechanism consists of 1 drive wheel and 3 support wheels to propel the arm through the warp and fetch the thread laid ready by thread selection

MODULE 10: GRIPPER

INTRODUCTION

This chapter will contain the current solution around the gripper. The gripper has to meet several requirements as allowed weight and space. Allowed weight for the gripper is 0,3kg. Available space for the gripper is described in “Total storage space” (D-00.A.10-EM) on page four. The gripper has to match the solution for the thread selection system. Desirable design for the gripper is to produce minimum friction between the gripper contact area and warp threads, at the same time as the gripper has to be stable.

GRIPPER HOOK

The main reason why this solution is chosen is because it is much simpler than solutions that are discarded. This solution is based around a hook, which is attached to plastic parts. The gripper will hook the thread and pull it over warp threads to the other side. This gripper can be integrated with the" Pendulum", "Overreaching arm" and "Moving overhead arm" thread selection solutions. The gripper is made of three parts. Top and bottom plastic part, where both parts are partly formed with the same shape as the gripper arm, which is desirable considering to the carrying capacity of the gripper arm. Last part is a simple hook. A hole through each part makes possibility to attach the hook to the gripper and also the gripper to the gripper arm. The bottom part is formed with two filets to avoid hooking between the gripper and warp threads. Gripper is illustrated below in Figure 3.

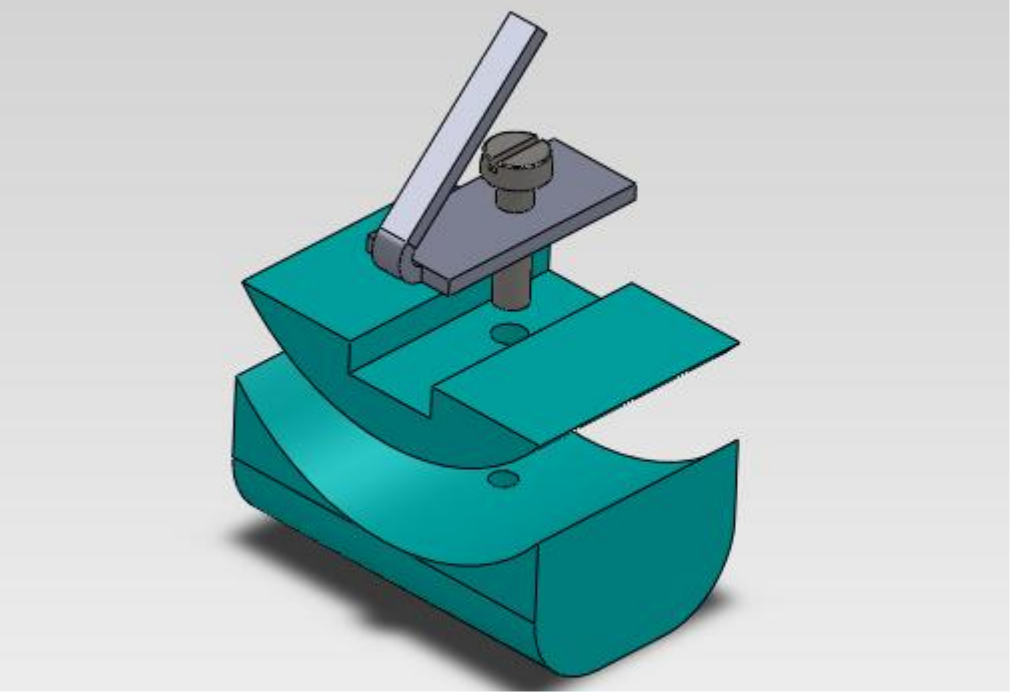

Figure 3: Gripper hook

MODULE 11: GRIPPER ARM

INTRODUCTION

This chapter will contain the current solution around the gripper arm. The gripper arm has to meet several requirements as allowed weight, size and appropriate attachment points. Available space for the gripper arm is described in “Total storage space” (D-00.A.10-EM) page four. The gripper arm has to match the solution for the thread selection system.

MECHANICAL SOLUTION

We have looked at solutions for what types of material and shape the gripper arm will be made of. The solution we want to explore is to develop a gripper arm that has the same characteristics as a measuring tape. This solution is also used in the Lego prototype and will be used in our final prototype. Main reasons why this solution is chosen instead of discarded solutions like “cable chain” are weight, size and noise. The type of the measuring tape is illustrated below in Figure 4.

Figure 4: Measuring tape

The function of the gripper arm is to move the gripper to the other side and back. It has to be stable and withstand the stresses that occur to avoid buckling in the movement process. Therefore we had a Lego prototype test on this part where the arm appeared to be quite stable. The arm is fed by a feeding mechanism which is located at the bottom of the module, also called “garage”. The arm is stored through a feeding system and along casing with 2 angles of 90 degrees. The position of the arm is illustrated below in Figure 5.

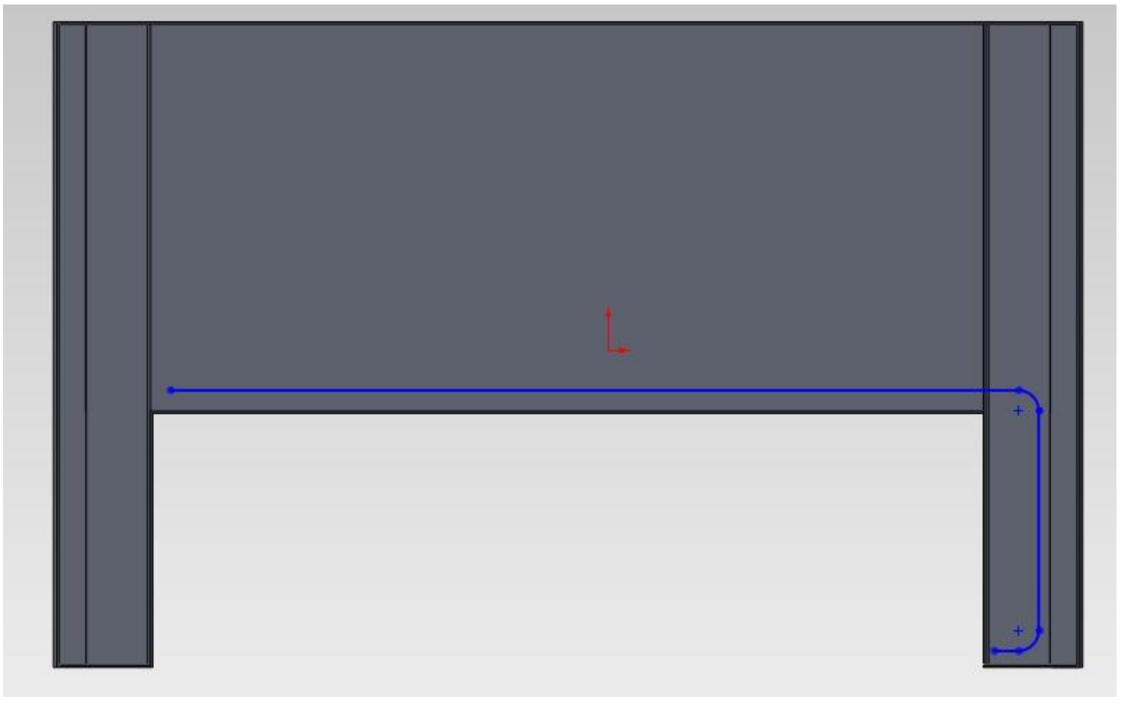

Figure 5: Position and storage of the arm

There are two existing holes on the end of the arm (measuring tape) where the gripper can be attached, but only one hole is used on the prototype.
It is illustrated below in Figure 6.

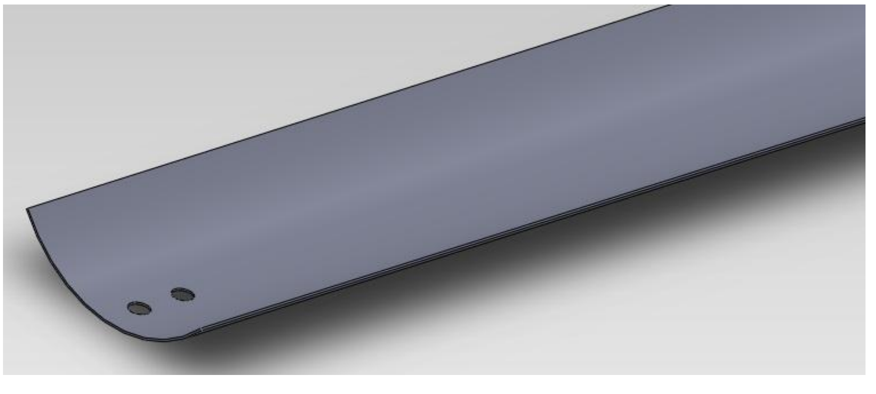

Figure 6: Attachment points for the gripper

MODULE 12: FEEDING MECHANISM FOR GRIPPER ARM

INTRODUCTION

This chapter will contain the current solution for the feeding mechanism and the discussion of why it is chosen. The function of this mechanism is to store and feed the arm out of the garage, and over to the other side of the module. It also has to maintain and stabilize the gripper arm while it is fed.

AVAILABLE SPACE

The motor has to fit the available space on TC2. Figure 7 illustrates the available space view from above. The lower corner house of the feeding mechanism also has to fit in the available space. If we have to use the whole length (196 mm), the motor has to rest on top of the corner house.

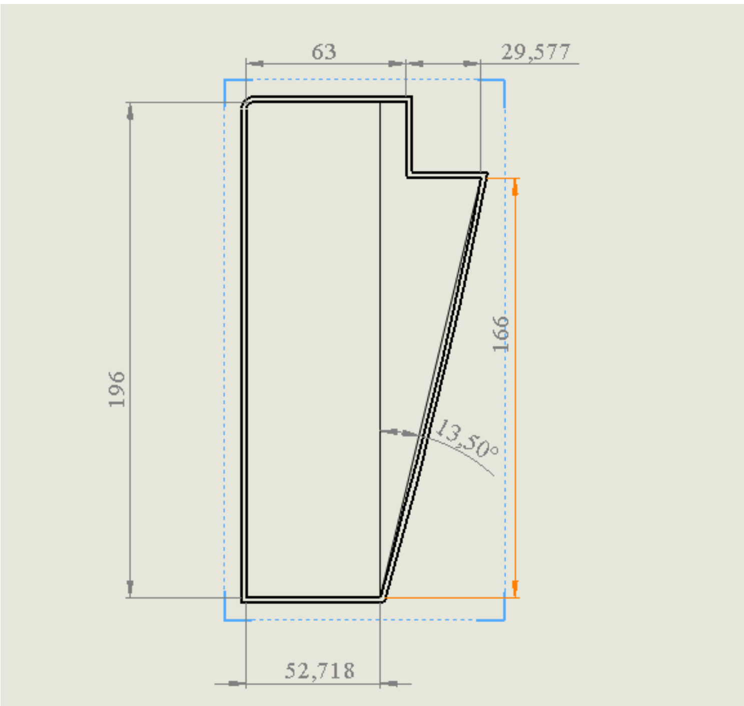

Figure 7: Available space for motor

All of the motors and the controller's technical data and calculations are described in the Technology document (D-00.A.17-EM).

The group will solve this by prototyping with a different motor then the one that will be used/proposed used in the final product. The motor used in the first prototype will be ME060AS102, this is a 24 V BLDC. This was chosen because our employer had this motor at their disposal. It also seems to have the correct performance figures needed to get satisfying results. Alternately we have research 12 V motors which are both stronger and weaker, that can replace this prototype motor.

The group wants to use BLDC motors because they:

- Yields high output torque in relation to size.
- Have to perform repeating cycles fast, often and over a long time.
- Have low maintenance.
- Have acceptable torque and speed output
- Are quiet.

The ME060AS102 and the motor controller 24ZWSK15-30-S will be used in the prototype. The goal is to:

- Determine the required torque through testing.
- Develop and test a regulating algorithm for the motor. We want to find out how fast we can travel the whole distance without losing control and get slip between the pulley wheel and gripper arm.

The program algorithm will be tested both in Visual Studio and AVR studio. Algorithms will be tested on both the Lego prototype and the actual prototype.

Physical measurements when the prototype is finished will determine whether or not out requirements are met.

POSITION SENSOR

This was first discarded midway through the project. There were reasons to believe that the motor for the feeding mechanism could be controlled only by the output pulses from the motor driver. Early module testing were successful, but when external components where implemented this didn't work. When the group started testing on the prototype the problem was that we couldn't avoid getting some degree of slip between the pulley wheel and the gripper arm. When cycles were run over time the gripper slowly changed its position. The accuracy became so bad, that it was no chance it would meet our requirement. It was so bad the prototype wouldn't work either.

The sensor we use is a inductive sensor we got from our BUC. This senses the gripper arm and is normally high when the arm is in motion. If our employer decides that a position sensor is needed, a better solution could be to use a photo sensor. This could be mounted further away from the gripper arm and could be placed perpendicular on the arm instead horizontal on the arm. The sensor we use is also too big to meet the space requirement, so a smaller sensor has to be used. The timeframe from this "problem" was discovered to the hand in, was too short to get a hold of a sensor that from an external supplier.

The feeding mechanism contains three parts:

- Bottom corner house which is feeding the arm out, and also stables and leading it to the next part of the feeding mechanism.
- Plan A and plan B of vertical house which stables and leading the arm to the next part of the feeding mechanism.
- Upper corner house which stables and leading the arm out of the feeding system.

BOTTOM AND TOP CORNER HOUSE

This corner house is containing four wheels with the same shape as the measure tape which we are using for the gripper arm. One of them is a feeding wheel with the same shape as upper side of the arm. Two of them are support wheels shaped as the bottom side of the arm. The last wheel is also a support wheel, but the shape is flat because the arm is flatting out at the corner. All support wheels can be tightened in the direction of the feeding wheel which is desirable.

There is also an idea to adjust the whole corner house considering to the right direction of the arm movement. Upper corner house is nearly identical to the bottom, except for the shaft through the feeding wheel and motor attachments. Upper house is there just to stabilize and lead the arm into the right direction and therefore there is not necessarily to have a driving shaft through. First of all we are going to try prototype without upper house. The whole bottom/upper corner house is illustrated below with section view in Figure 8.

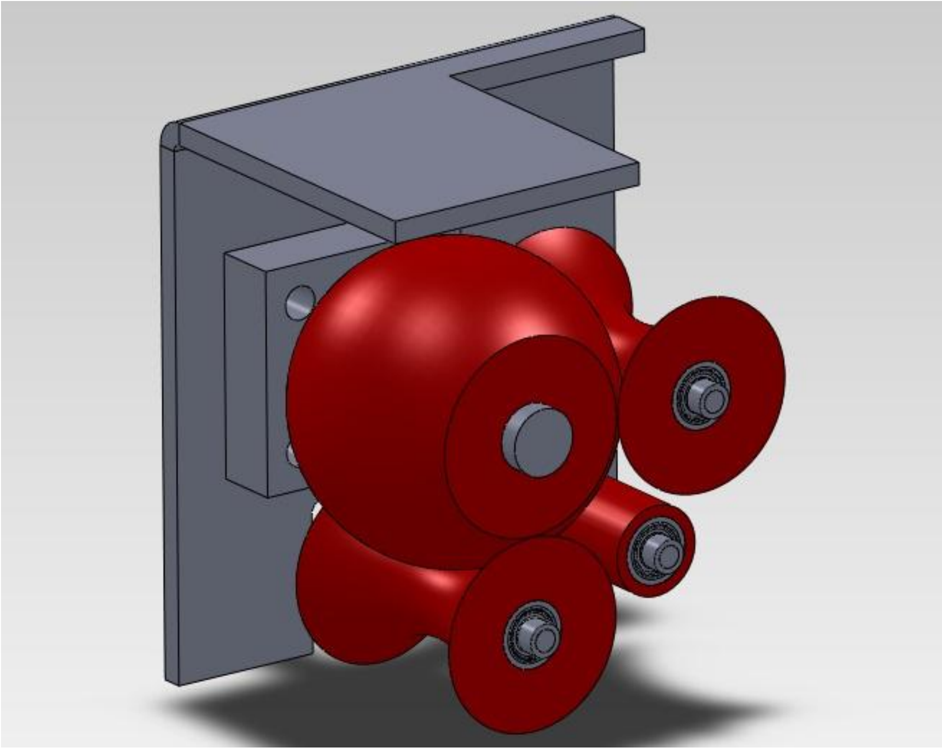

Figure 8: Section view of the bottom/upper corner house

VERTICAL HOUSE

This house has a little bit different form from the one in the corner and contains five wheel slots. The house is longer and each slot can contain two wheels, which means that the house can contain up to ten wheels depending on how much stability we need. Wheel shapes are the same as in the corner house. One of them is shaped as upper side of the gripper arm and the other as a bottom side. Every wheel is adjustable in the wheel slots. Vertical house is illustrated below in Figure 10.

SIMPLE VERTICAL HOUSE

This vertical house is just a simple version of the previous vertical house. This house does not contain any support wheels and will be tested as first design to conclude if it gives enough support to the gripper arm. Simple vertical house is shown in Figure 9.

WHOLE FEEDING MECHANISM

Plan A for feeding mechanism is to use only bottom corner house and simple vertical house and test if it gives enough support. Design of plan A is shown in Figure 9.

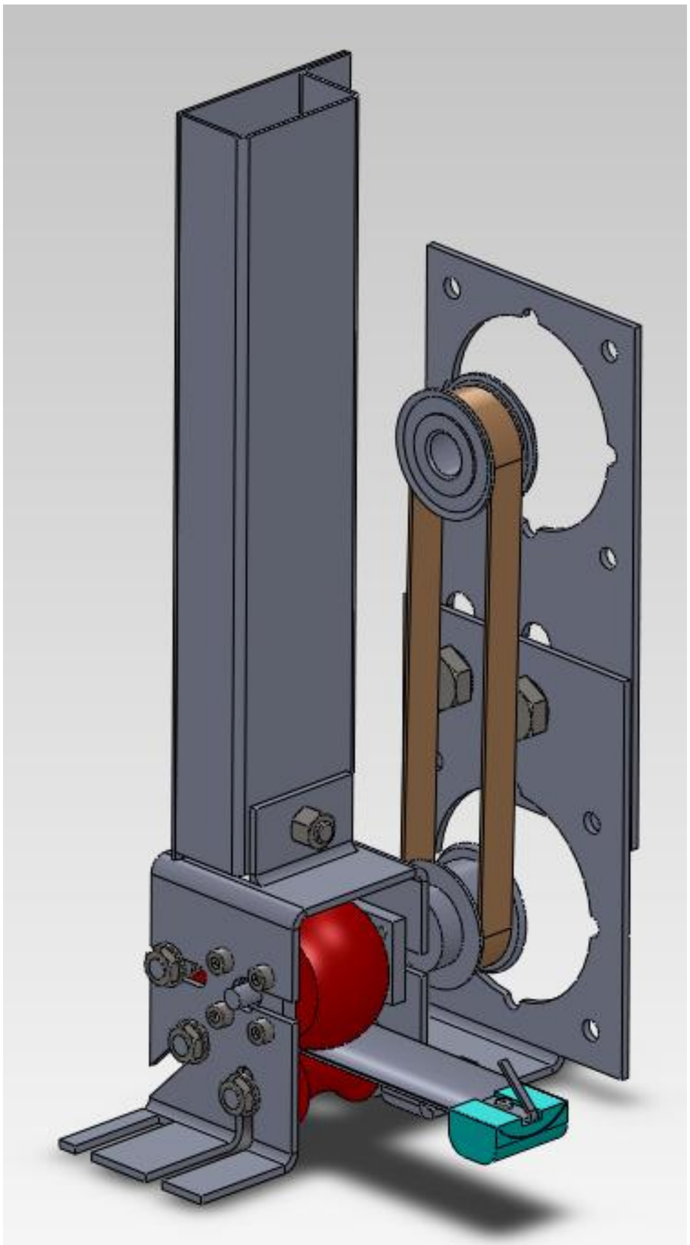

Figure 9: Design of plan A

Plan B is to use vertical house with support wheels and both corner houses if plan A does not give enough support. Design of plan B is shown in Figure 10.

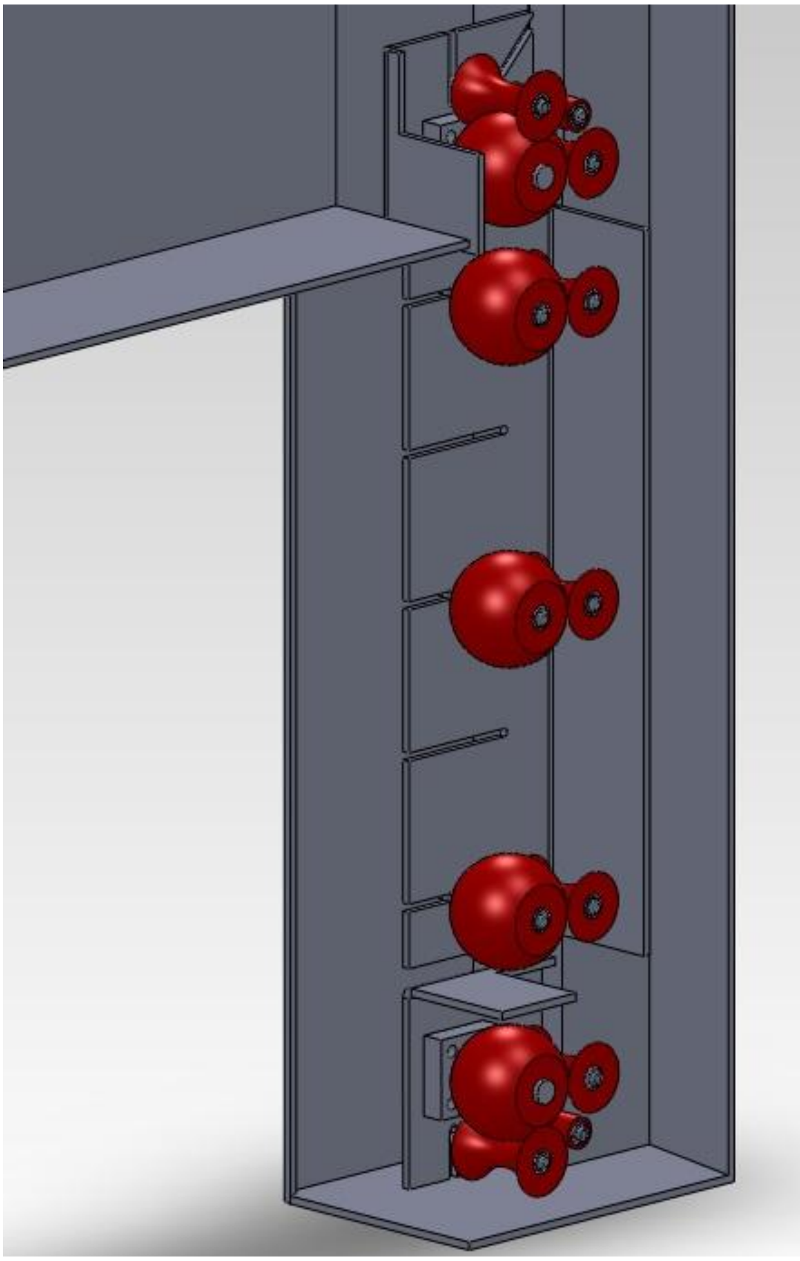

Figure 10: Design of plan B

MODULE 20: THREAD SELECTION SYSTEM

INTRODUCTION

This chapter will contain our ideas and solutions around the Thread selection system (module 20) and explore ideas around the Thread cutter system (module 21). As per now, the fetching mechanism (gripper with arm), and thread selection, will be on different sides of the loom. The area to be used is described in "Total storage space" (D-00.A.10-EM) page two. The area is smaller than 97x200 (mm) in the ground area. Seen from a realistic view, the space is more like 80x120mm.This is going to be referred to as the “garage”.

MOVING OVERHEAD ARM

This is our main idea. It works very similar to the pendulum arm idea, which can be read about in “discarded design and analysis” (D-00.B.23-EM), but instead of moving like a pendulum, the arm is mounted to a moving overhead beam. This eliminates the under swing that the pendulum arm has. With the arm moving in just one axis, the garage width is not constrained by the tension mechanism. The overhead beam will be driven by an electrical motor. For later use, pneumatic pistons can be used to control the overhead beam. This idea needs one unit per thread, same as the pendulum arm. But this design has a greater possibility to be paired up (4x2), which gives us a possible unit width of 2cm. The doubling of width gives us more room for the unit solution and therefore the mechanism can be far better.

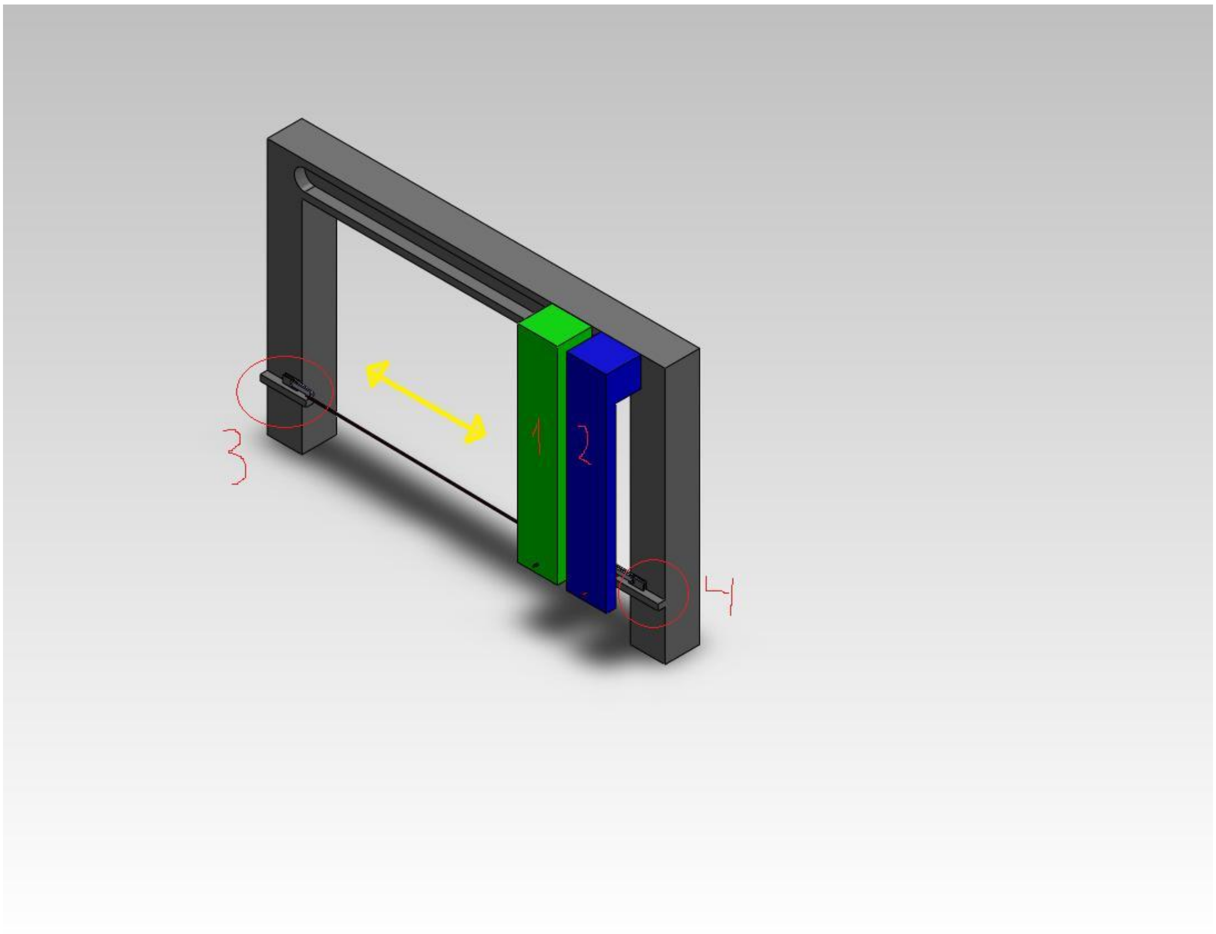

Figure 11: Moving overhead beam

The Figure 11 above illustrates a pair of units. 1 and 2 are different units were arm number 1 is now ready for thread pickup. The thread is tensioned between the arm and the holding mechanism (seen as number 3 on the figure). Arm number 2 is in “zero-position”.

THOUGHTS AROUND THREAD SELECTION

The mechanism around thread selection has been one of our main headaches in the project. The limited space and the required speed are the main concerns around the ideas that have been presented. The idea around a moving overhead beam is the solution for this project. The units will be paired up, giving us 2 cm for “one” unit in width.

BACKUP DESIGN

We made a backup design since the original design was discarded. The backup design is a much cheaper solution. Thus the backup design will not fit on the given space by Tronrud Engineering (D-00.A.10-EM). The original design consisted of two modules, each module with four arms. A total of eight arms are accomplished if the two modules are mounted side by side. The backup solution consists of one module with two arms. We discarded the original design because of expensive components. The TN10 pulleys are machined after our specifications. We needed four motors for one module, and the delivery time on pulley wheels and timing belts were considered to be a threat for our project. The pulley wheels on the backup design are standard components in stock, also much cheaper. We were given two motors from Tronrud Engineering for testing; these motors would not have fitted in the original design. The backup design will work the same way as the original design, and is good enough to test and illustrate our solution.

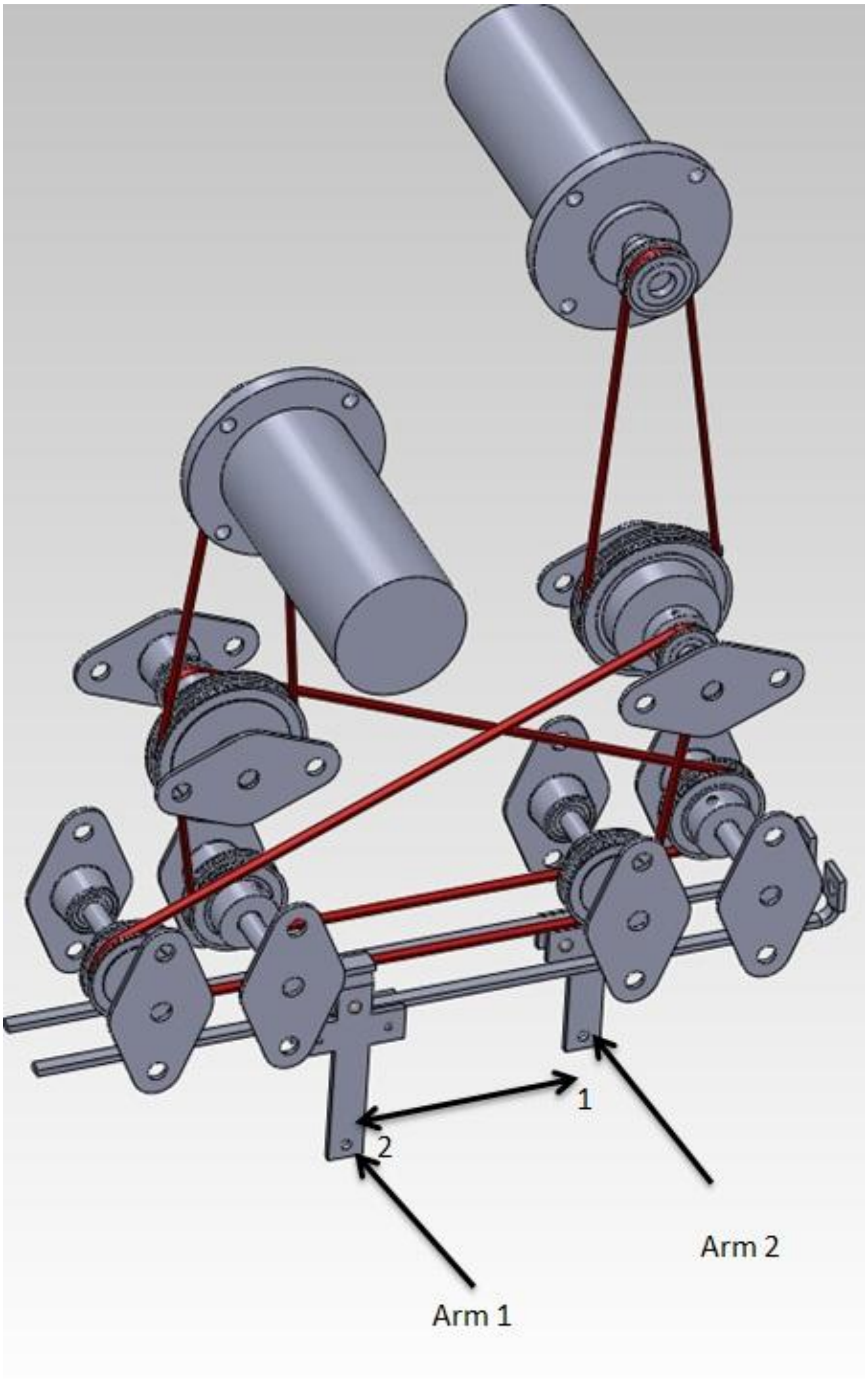

Figure 12: Backup thread selection

Figure 12 shows the concept of the prototype. It is very similar to the current design with eight arms. The concept is the same; on Figure 12 Arm 1 is in the “ready for gripper position” where 1 and 2 on Figure 12 is the path for Arm 1. 1 is the initial position and 2 are the “ready for gripper position”. Arm 2 is in the initial position.

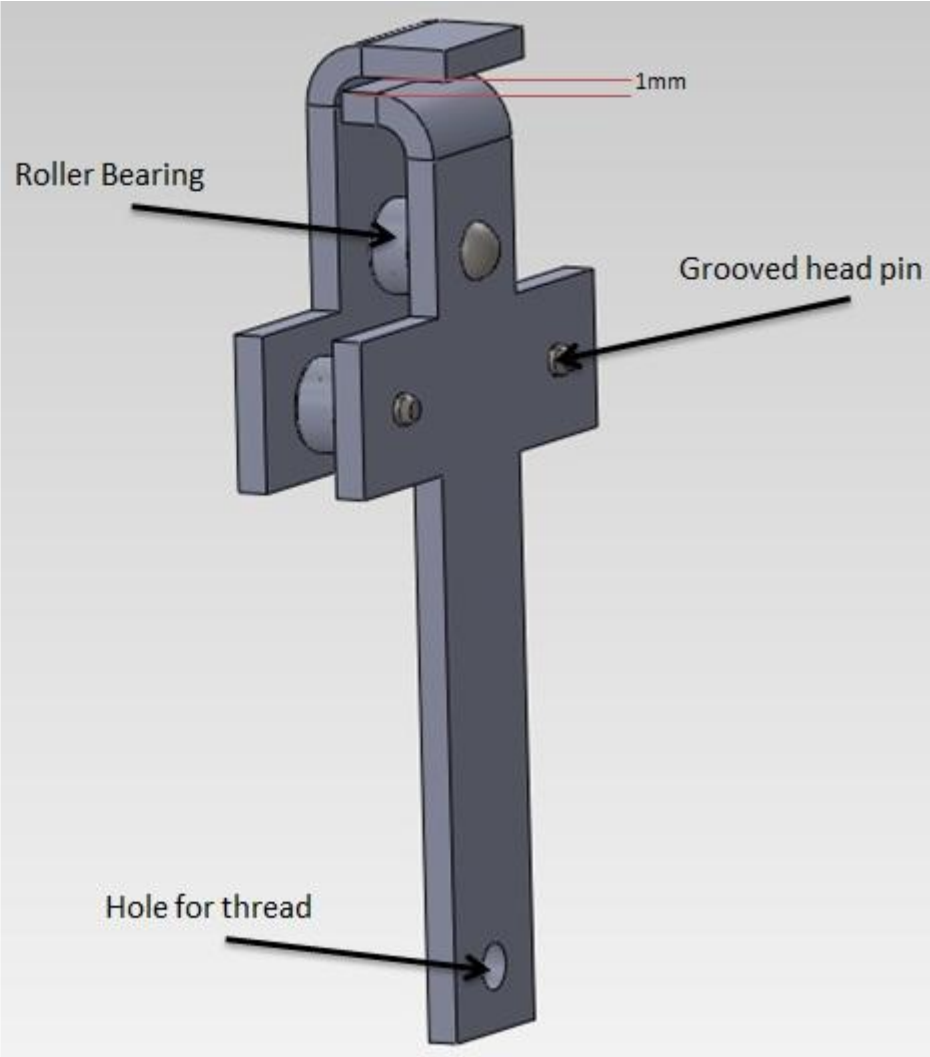

Figure 13: The arm

The arm, illustrated in Figure 13, will consist of two steel plates which are attached with round head groove pins. Between the steel plates on the pin bolt, it is attached a roller bearing with shims/washers on each side of the roller bearings, pressing on the inner ring of the bearing. At the bottom of the arm there will be machine pressed hole with diameter 2 mm for the thread. The timing belt is attached through the top of the arm. The gap on the top is 1mm and the height of the timing belt is 1mm.

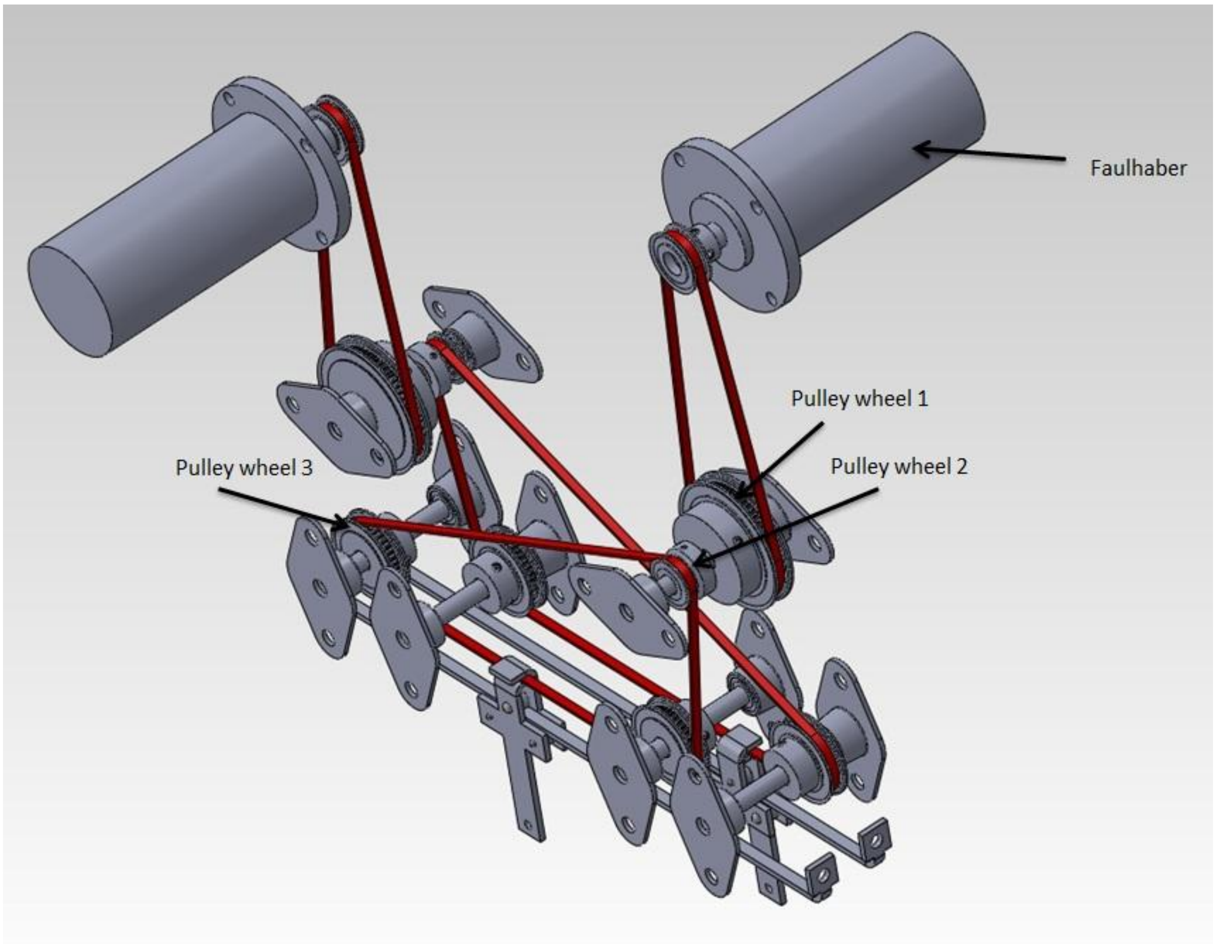

Figure 14: Whole System

When the Faulhaber starts to rotate seen in Figure 14, Pulley wheel 1 will drive pulley wheel 2. This is because pulley wheel 1 and pulley wheel 2 is mounted on the same axle. The shaft is mounted into the flanged press bearings. Pulley wheel 2 drives the lower pulley wheels (pulley wheel 3) which results in horizontal movement of the arm. The motor will also be driving both ways. The pulley wheel on the motor has 20 teeth and the pulley wheel 1 has 60. The reason why we have chosen pulley wheel 1 and pulley wheel 2 is only for gearing. In the original design the small motors have a very small torque; this is why we chose to gear it. In the backup solution it is not necessary because the Faulhaber motor has much greater torque. The reason why we chose to use gear at the backup were to have as similar system as the original design as possible. All pulley wheels are double flanged; this means that it is an edge on each side which prevents the timing belts to slip off. They are also with fitted with a hub. A hub is kind of an adaptor, fitted on a shaft. This is so we can fasten the pulley wheels with the set screw to the axle.

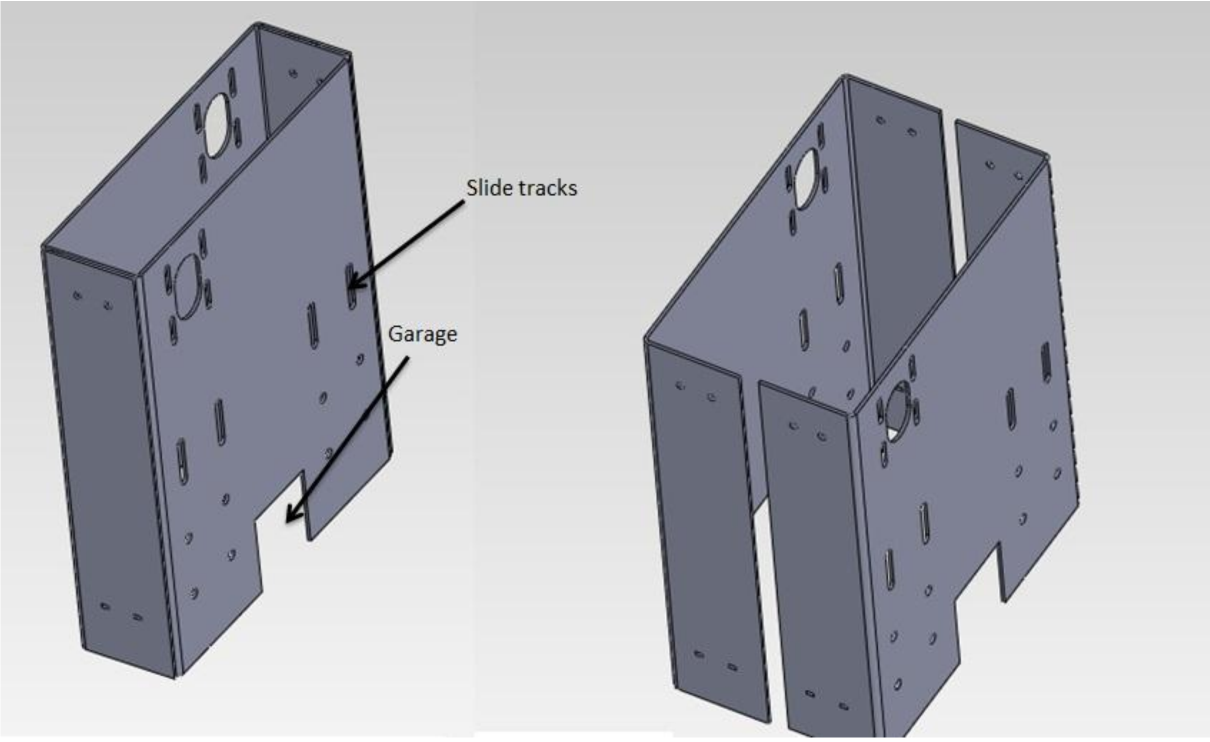

Figure 15: Casing

The prototype casing is also similar to original design. The main difference is the size. The prototype will therefore not fit on the TC2. The backup design also consists of 2 thin steel plates, instead of one on the original design, as shown on Figure 15. The casing will contain the thread selection system and the thread holding and cutting mechanism. The garage is where the gripper enters to pick up the thread, slide tracks is for adjusting the pulley wheels. All slide tracks and holes for bolts are machine pressed.

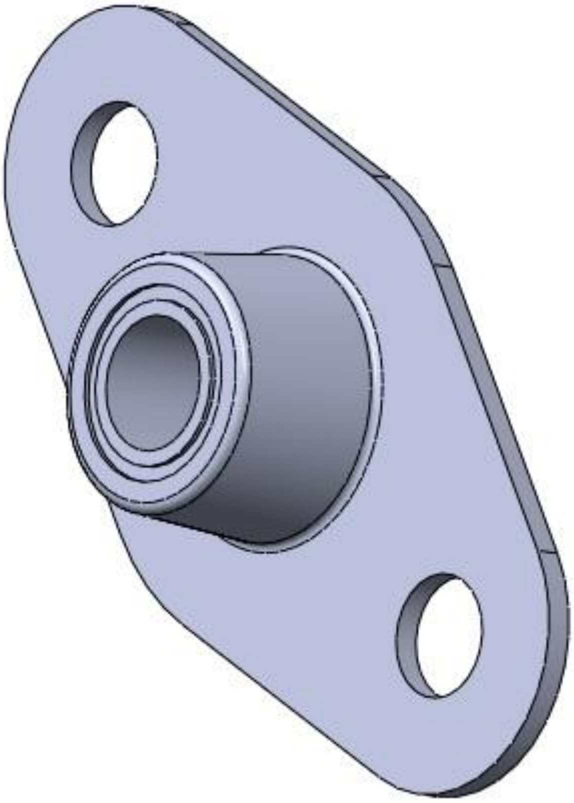

Figure 16: Press bearing

The press bearing, illustrated in Figure 16, is attached to the casing with two bolts. The position can be adjusted in the slide track of the casing. The bearing has a diameter of 6mm. The shaft will be inserted by press and this sets the requirement for the diameter of the shaft. The diameter of the shaft has to be maximum 5,990mm and minimum 5,978mm.The tolerance of the shaft has to have a 0.4µm or finer finish.

The arms are now being controlled by the Faulhaber MCBL 2805[1] controller, with commands delivered over serial. The MCBL 2805 controls a Faulhaber 3564 K 024 B K1155 BLDC motor[2] with a 38/1S planet gear[3] (See Technology document for BLDC explanation).The program is divided into 3 parts:

- One continuous loop, waiting for commands
- One for extracting the arm
- One to retract the arm

These commands for these functions are given by the master controller. The Controller for the arm is given the node address 1. Commands without node address in it, goes for both controllers. The program starts with an initiation of the motor:

GOHIX

LA0

AC500

SP4000

M

After the preliminaries are set, resetting the motors position, setting acceleration and top speed, we go on to the continuous program itself. First the continuous loop that the controller runs in while it waits for commands.

A1

JMP1

So then comes the part of the program that propels the arm forward. This will make the thread ready for pickup by the gripper. Setting the desired distance the motor shall run and after the motor has reached its position, and the arm, the controller stops the motor.

A2

LA50000

M

JMP1

After the thread has been picked up, the arm needs to retract. I.e. the motor must run back to its initial position. And again sends a confirmation to the master controller that the arm has reached its destination.

A3

LA0

NP0

M

JMP1

See technology document for more descriptions of the commands. The command "Ax", with x as a number 0-255, is a jump-in point, called by "JMPx". The make the code easier to understand, a simplified activity diagram has been made;

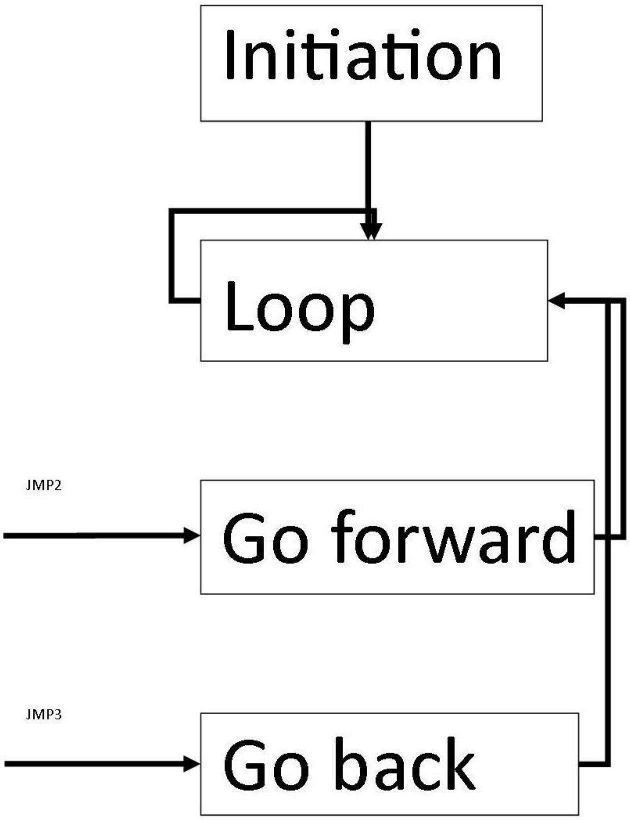

Figure 17: Activity diagram

The controller runs on its own after the command has been received. If the controller receives a “JMP2” when in the forward position, the arm will not move, but the controller will confirm that the arm/motor is in the commanded position.

The cutter/holder is also controlled by a Faulhaber MCBL 2805, with node address 2. This program is rather simple, as looks very similar to the controller for the arm.

GOHIX

LA0

AC500

SP4000

M

Has the same initial programming as the controller for the arm.

A1

JMP1

Here is the "waiting" loop

A2

LA5000

M

JMP1

Since the motor should only turn some (approx. 1/3 of a turn), to lift the cutter/holder, so release the thread.

A3

LA0

M

JMP1

This returns the motor to its zero-position and now the cutter/holder is closed.

PCB

Electric wiring diagrams can be found in Attachments->Electrical_Wiringdiagrams.

This card has only been designed for prototype purpose only. The card was made because:

- We wanted to move components from the breadboard to PCB making it easier to wire the finished prototype
- We wanted to learn development software for designing PCB.
- We wanted to learn how we could make our own PCB

There are two PCB on the prototype. One contains the voltage regulator and the other controls the hardware control circuit. The PCB which contains the voltage regulator is not designed by us, but we mounted the components on this card.

The design of the PCB were done with Multisim Ultiboard 11.0[4].

Figure 18 shows a print screen of the drawing of the PCB in 2D and 3D.

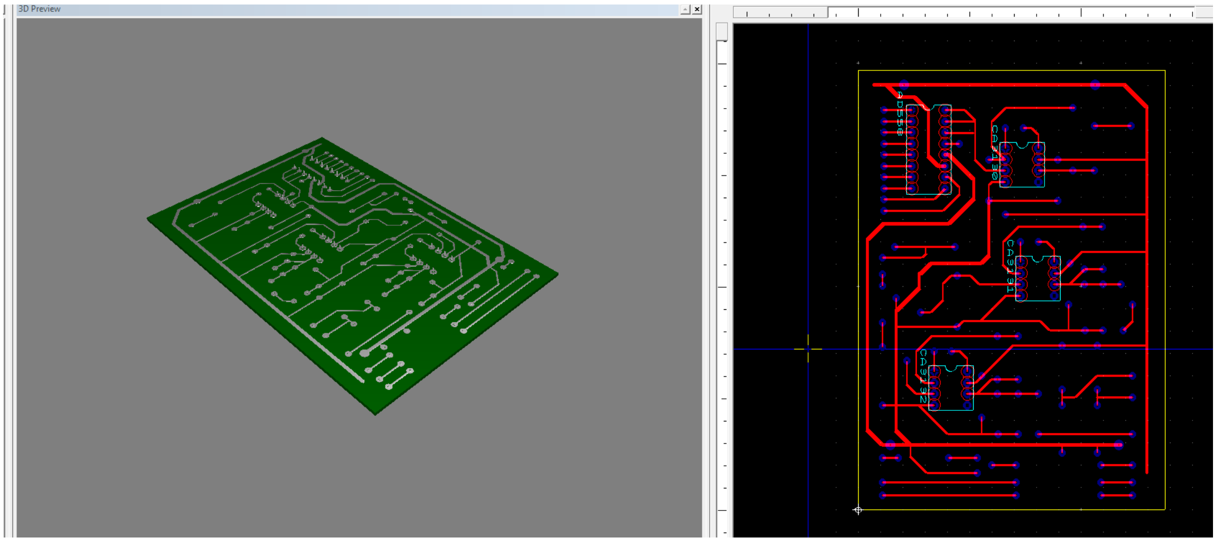

Figure 18: 3D and 2D drawings of the PCB

The PCB will contain 7 sub circuits:

- One 8 bit DAC, AD558
- One voltage follower with gain, CA3130
- Two voltage follower circuits, CA3130
- Two voltage dividers for MUX input
- One voltage divider for sensitivity setting for weft sensor

Figure 19 shows the inputs and outputs of the PCB. It also shows what areas are used for the different components.

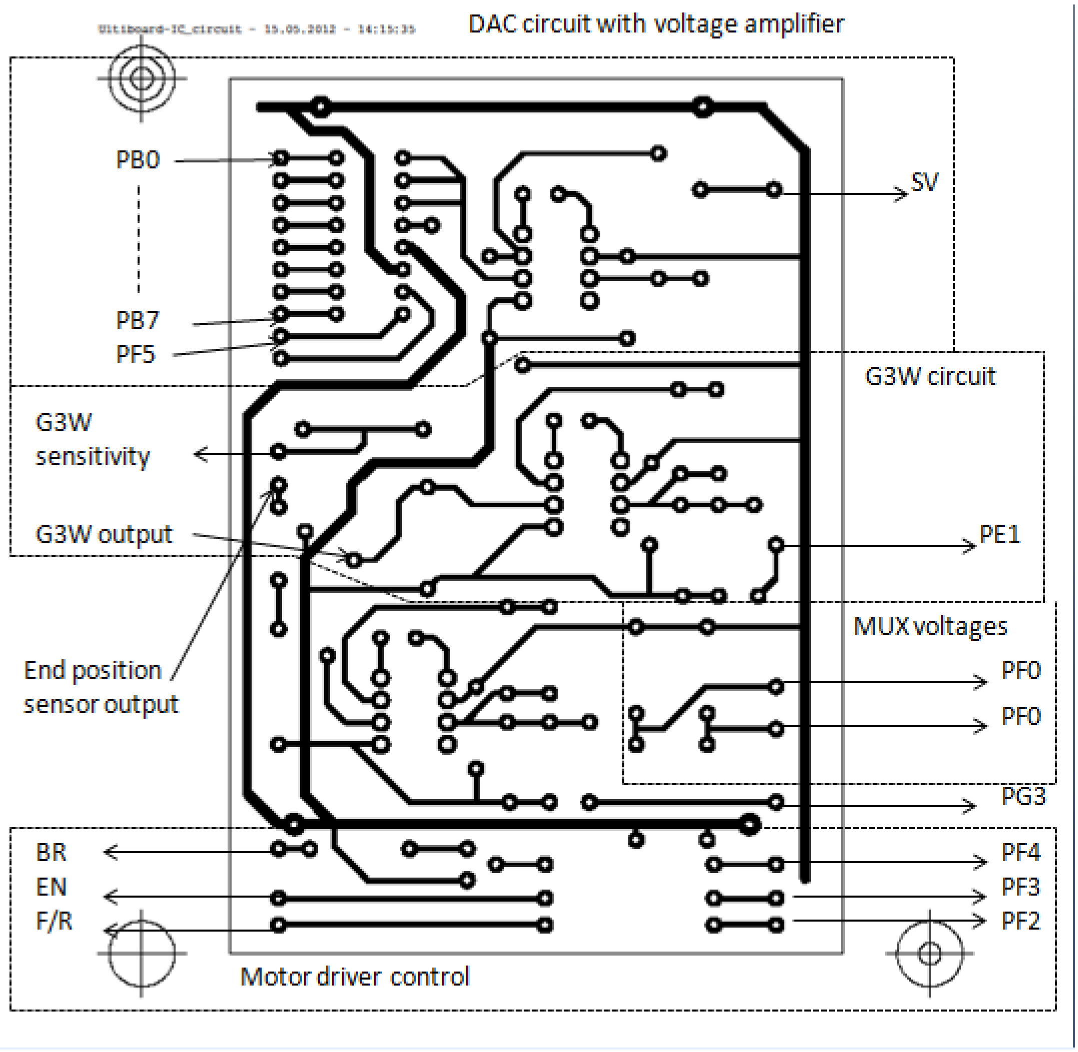

Figure 19: PCB input/output

Wiring diagrams for the prototype, PCB and sub circuits can be found in Electrical wiring diagrams (D-00.A.35-E).

Were planning to use IC components with DIP packages/through holes. This enables us to do tests on breadboard, and still used the components on breadboard if a PCB isn't developed. Though holes components are also much easier to solder, therefore this package is selected since we don't have much experience with soldering.

VOLTAGE REGULATOR

The voltage regulator has been tested for prototype use. The TC2 has a mounted 12 V supply rail which our module will eventually use. Buts since our motors use 24 V and all of the electrical hardware is dimensioned for 12 V we needed a 24 to 12 V regulator.

MODULE 22: THREAD FEEDING SYSTEM

MECHANICAL SOLUTION

The thread feeding system is basically the path of the threads from the thread holding system to the thread selection system. The path must be accessible, so that it is easy for the user to change spool and thread. It is important that the thread feeding system do not have any sharp edges that can snap a thread or give it unnecessary much friction. The thread holding system will be equipped with a weft sensor that can detect if any of the spools becomes empty for thread. This is explained more in the chapter below. Our solution for the thread holding and feeding system may require some sort of static thread buffer. In that way, the weaving process or pick can be finished even though a spool is empty.
Our problem was to make a solution which was not too complicated. We thought about using an extra spool, an arm that hooked a thread, an arm that dragged a thread and so on. In the end, we went for a solution where sensors are placed right after the thread holding system, and it relies on that the path length between the weft sensor and the thread selection system is larger than the pick itself. This makes the buffer; but the let-off acceleration of the threads from the spools is not reduced. This is not our concern anymore, because our solution for the thread holding system uses fixed spools. To guide the threads on the prototype from the sensor to the thread selection system, we will simply use ordinary hooks.

MODULE 23: THREAD HOLDING SYSTEM

MECHANICAL SOLUTION

This chapter will contain our ideas and solutions around the Thread holding system (module 23). Our employer expressed a wish that the spools to be mounted on our module instead of in separate racks. We have concluded that the spools then have to be mounted on the area above the beater. The area to be used is described in "Total storage space" (D-00.A.10-EM) page 2 and 13, which is basically 78cm wide, 35cm high and 15cm deep. We have agreed that the preliminary maximum spool size is 10cm in diameter (11cm at bottom for the conical) and 15cm high.

We will only make one half of the designed thread/spool holding system, because of prize and the fact that two modules will work if one module work under testing. It can also be mentioned that because the thread selection system only will take 2 threads, it is not necessary to have 8 spools for testing. The technical drawings for the spool holding system were sent to Tronrud Engineering before Easter, and were produced in the beginning of May. We will therefore not have the time to redesign a new system if the system fails. We cannot think of any mechanical failures except that it may be a problem to extract thread from the spools, resulting in snapped threads. This can be solved by spacing the thread tray up from the chassis/cage, which will make a less negative let-off angle for the threads.

TWO ROWS OF VERTICAL SPOOLS, WITH TWO THREAD TRAYS

This solution have two rows with 4 spools side-by-side, and two common thread trays - one above each row. This solution is about 10 cm higher than our available space, but it seems to be the best solution, and it's better to go above the area than beside it.

This solution will deliver the threads at two places, which makes the approach angle better in case of the sensors.

In this solution, the spools will be fastened to a beam or plate. This can be done by screwing the whole center pin down through the spool. . Mounting spools will simply be done by leading the center pin through the spool, and screwing the whole package on to the spool holding system. Figure 20 is an illustration of our favored solution. Figure 21 shows a CAD-drawing of this solution, albeit one half of the module. It can be said that the spool holding system maybe is a bit wide, and that it later can be made smaller in a redesign. The solution requires an insert or disc above the spool that centralizes the spool. The spool holding system is based on buckling 2.5mm thick sheet metal plates to form a chassis (which maybe is a bit over-designed).

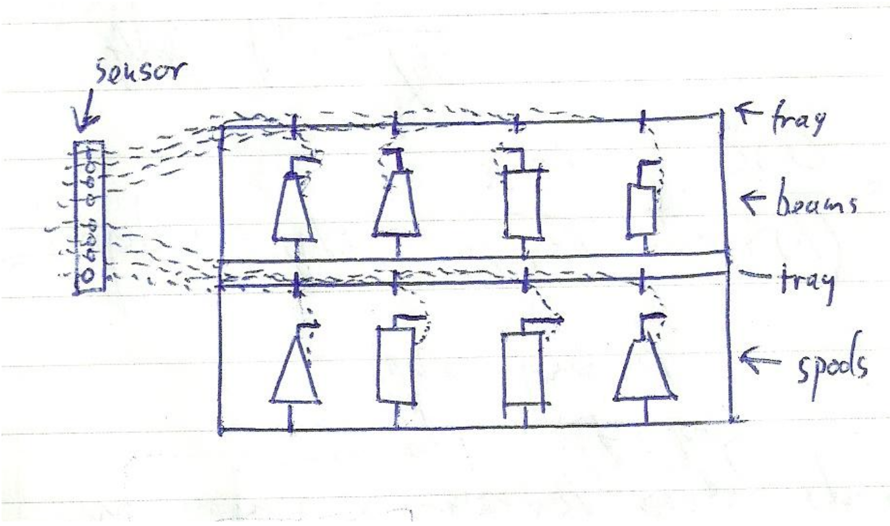

Figure 20: Newest solution with two thread trays

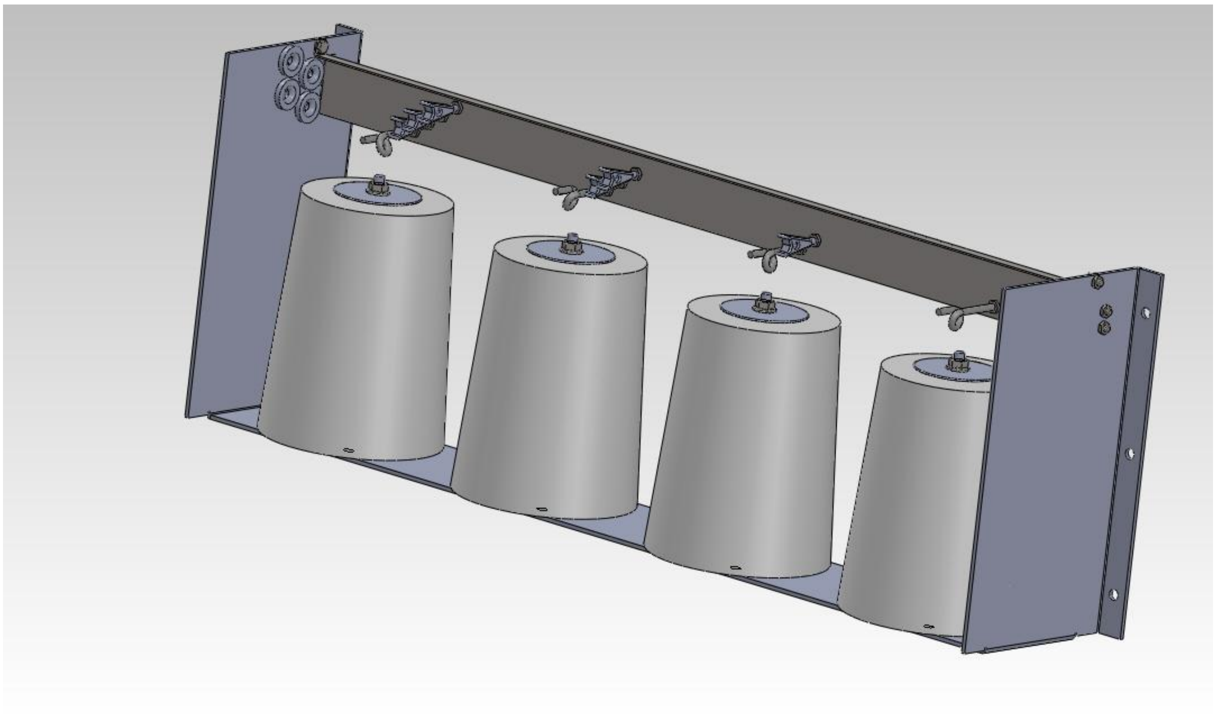

Figure 21: CAD of 1/2 of system

As it turns out, tests with cylindrical spools shows that pulling off thread straight from the spool is difficult without using too much force. This resistance occurs because of friction along the side of the spool. We want to keep the system with fixed spools, but need to redesign. We thought of a rotating arm on top of the spool, but this was thought of being too expensive and complicated prototype wise (see "Discarded design and analysis D-00.A.18-EM" for more information about the discarded solutions). We are therefore going for plan B, which is to only use conical spools. We have however designed a rotating arm for testing with cylindrical spools, as shown in Figure 25. This only requires a set of different locking discs to be produced to lock the conical spools in place. It is important that these discs are not larger than the inside diameter of the spool, because if they are, they will catch the thread and increase friction. The let-off angle of the threads can also be disturbed. In the prototype, we can use simply a large washer for cheaper testing.

The thread tray is designed to be buckled out of 1mm thick sheet metal. Hooks that will be distributing the threads will be fastened to the thread tray. The thread tray needs to be buckled at one point to keep its strength. Figure 22 shows and illustration of the thread tray. Figure 23 shows a CAD-model of the thread tray with hooks.

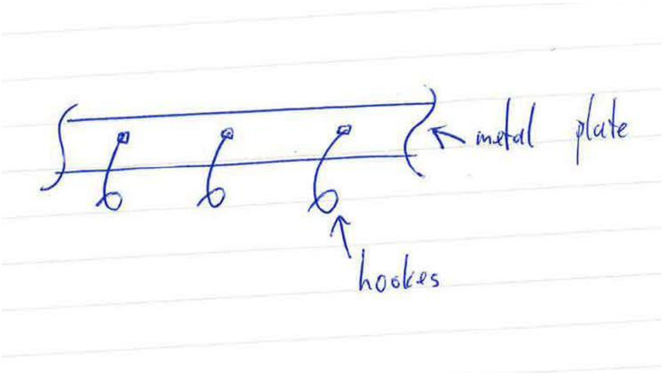

Figure 22: Illustration of thread tray solution

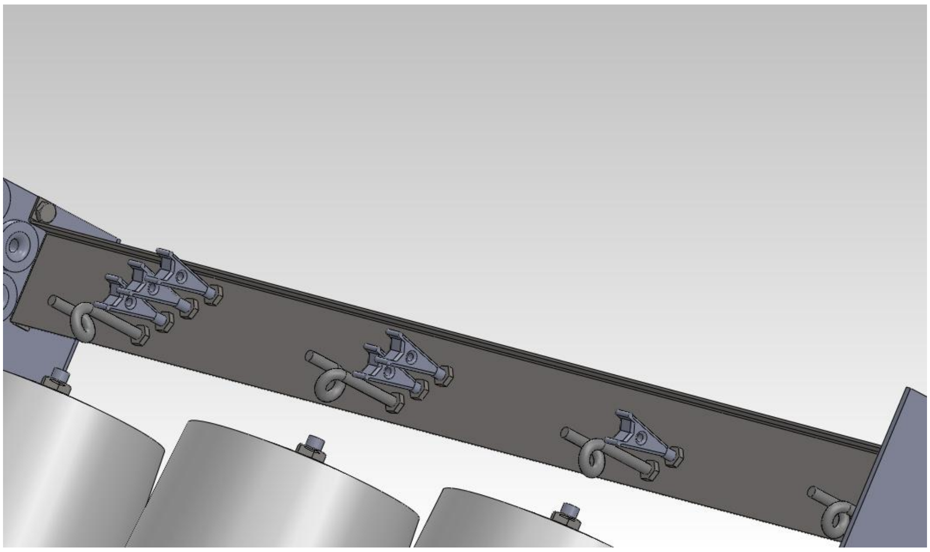

Figure 23: CAD of thread tray incl. hooks

The ceramic hooks and screws are made by Ascotex in England. We wanted to use these hooks and screws because they are easily available, and that we wanted to use parts that do not need to be made from scratch. Figure 24 shows a datasheet of these parts. It turned out that these hooks and screws were expensive, with a total price of EUR 77, - for one module. We have therefore decided to go for standard hooks from Biltema or Clas Ohlson and use some sort of modified screws or brake nipples used in cars to let the threads go through the sheet metal.

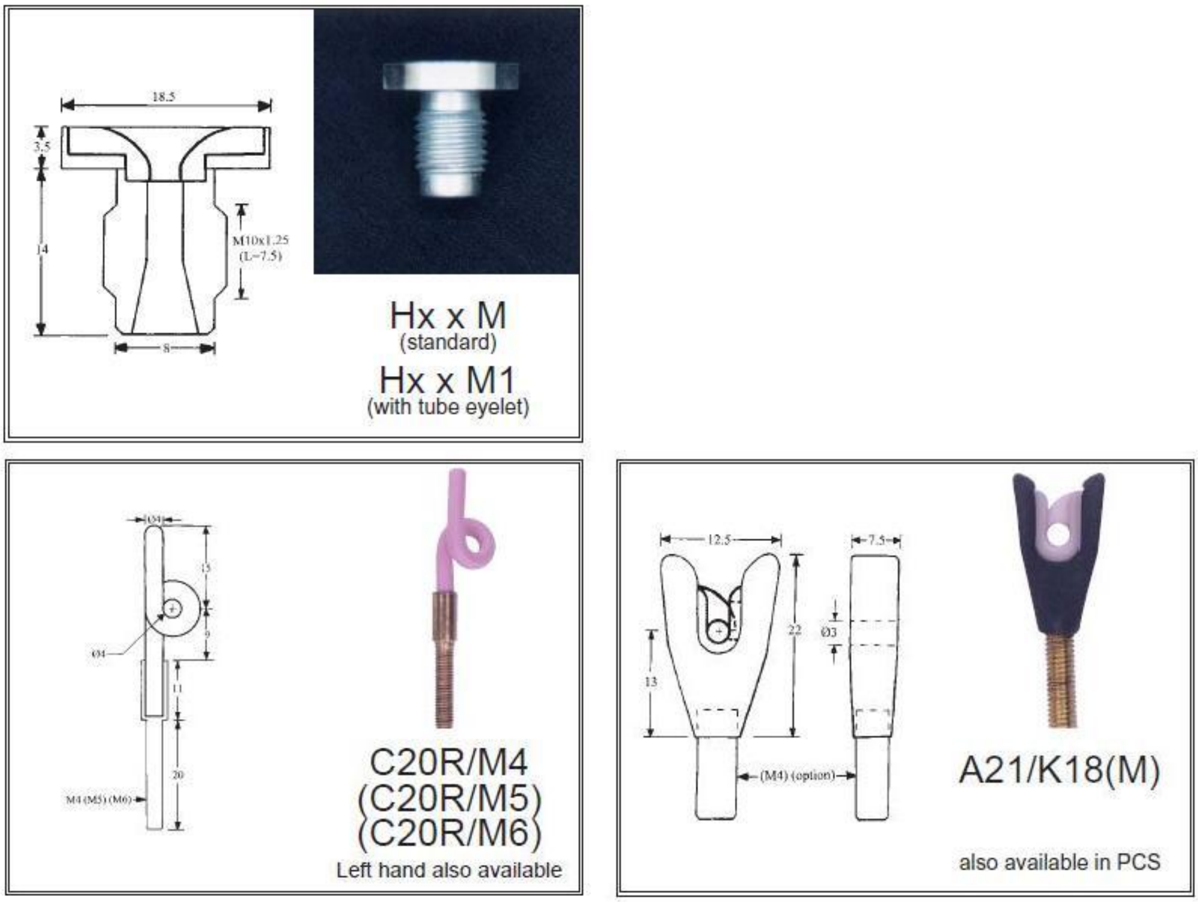

Figure 24: Hooks from Ascotex

After our second presentation, we were allowed to manufacture a single arm for prototype testing cylindrical spools. This arm can be mounted on the spool shaft. Figure 25 shows a CAD-drawing of the arm.

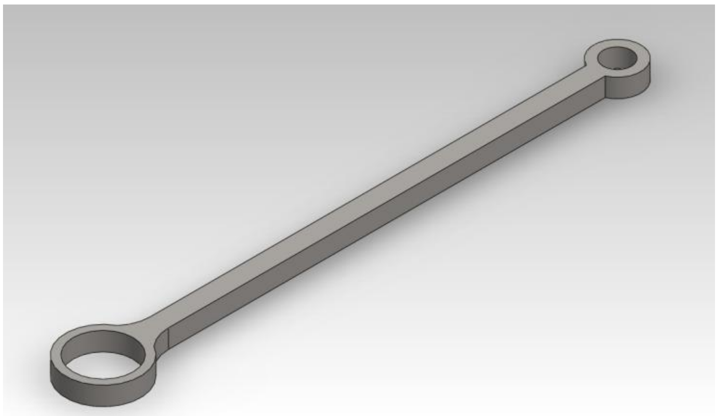

Figure 25: Rotating arm for testing

TECHNICAL SOLUTION

We are planning to use one sensor for each thread. We need these sensors to tell the system and the user when there's no more thread left on a spool. We see two ways to sense this: We can sense if the sensor sees/feels a thread, or if it sees/feels movement on the thread. We have not yet found any sensor that can "see" if there's a thread there. That would be difficult because the thread is so thin and not completely in the same position all the time, so it can be hard to detect.

We have contacted the company Eltex of Sweden, one of the world leading providers of thread sensors. They have never seen a yarn sensor that has the ability to detect that the yarn "is there" but not moving. The micro switch (as mentioned in Discarded Design and analysis D-00.B.23-EM) will not be suitable for our solution with a loose thread.

In this project, we have been using piezoelectric sensors, built into the weft sensor. It detects the small vibrations that the thread is creating when it's passing a ceramic eye or rod. The sensor will detect whether the thread is moving when it's supposed to or moving when it’s not supposed to. If it's not, it means that it's not more than one pick left before there's no more thread on the spool, that the thread is broken, or that the gripper failed to grab the thread. We have also added an additional feature that will secure that the gripper does not accidently pick more than one thread at the same time. We will use the built in analog comparator to compare the expected state with different fixed voltage values. You can see our weft sensor G3w in

Figure 26. For more technical information on this sensor, see Technology document (D-00.A.18-EM).

Figure 26: G3w weft sensor

MODULE 30: CONTROL UNIT

The control unit of this system is the ATmega128RFA1, it is mounted on the evaluation board STK600. The program uses 6 c files:

- MainProgram.c
- Run_FeedingMotor.c
- Serial_definitions.c
- WeftSensor.c
- Serial.c
- Configuration.c

To simplify the main program of this project, a simple flow-chart has been made:

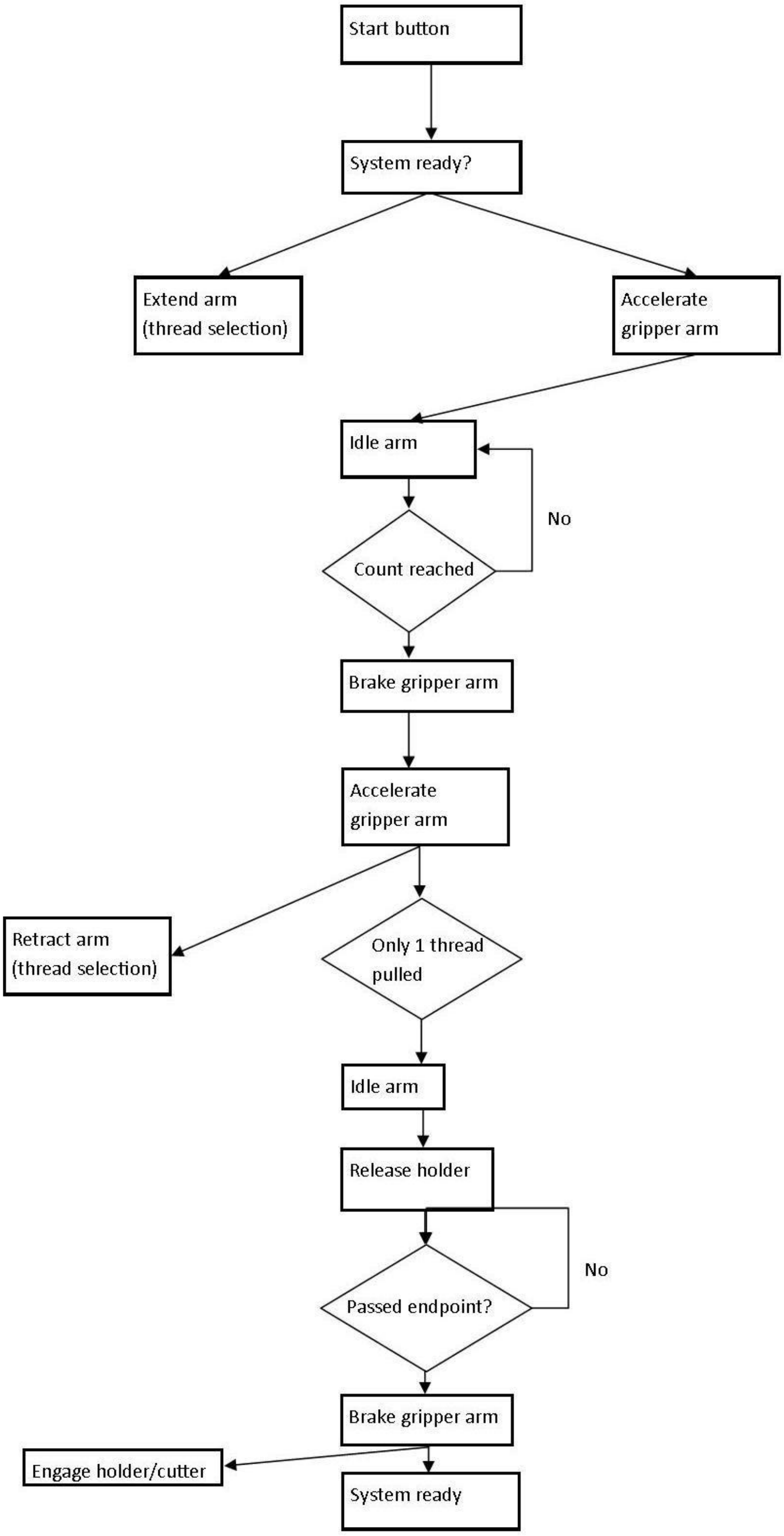

Figure 27: Flowchart

The figure above, show the flow of the program, everything on the left is sent over serial to the Faulhabers (MCBL 2805). This flowchart does not take bigger faults into consideration, since there is many routs the system can take, therefore the chart would be to complex and hard to make too much sense out of.

MAINPROGRAM

Global variables used in our program defined as (all are “int”):

- **real_endoint**:
  The real endpoint is the number of pulses the gripper has to travel in order to pick up a thread at the other side. When the gripper returns, the real endpoint is set equal to number of pulses the gripper has traveled backwards. This is done to compensate for a too short or too long backwards cycle.
- **measured_endpoint:**
  This variable is updated at the endpoint on the other side. This will be used when the gripper runs backwards towards its start position. The measured endpoint is set equal to the count when the motor has come to complete stop.
- **counter:**
  The counter is variable which can be used if the total distance one way will result in over 255 pulses.
- **first_idle:**
  Defines the number of pulses that has to occur before the compare A interrupt triggers when the arm is moving forwards.
- **second_idle:**
  Defines the number of pulses that has to occur before the compare A interrupt triggers when the arm is moving backwards.
- **portB_value:**
  Defines the PORT B output pins, has to be set between value 0-255.
- **forward:**
  Forward is set to one, when the motor is propelling the gripper/gripper arm forwards.
- **backward:**
- Backward is set to one, when the motor is propelling the gripper/gripper arm

- **run:**

  This variable is given value one as long as the motors are running is running.
- **error1:**

  This variable is set one if an error occurs.
- **state:**

  This is a state variable used to set the different states of the motor when it's moving backwards or forwards

The main program runs configurations for the ATmega128RFA1 before it starts the while loop which controls our prototype. In the while(1) loop, the program does four checks:

- If swith0 is pressed and the gripper is in start position and no errors (error1) has occurred the run variable is set to one, this initiates one cycle of the gripper arm
- If switch0 is pressed and the gripper isn't in start position, the gripper will be reversed in to start position.
- If switch0 is pressed and an error has occurred. The feeding mechanism will reverse the gripper into start position. If the error is still present, for example the gripper holds two threads, the gripper will stop again.
- As long as the run variable is set to one, the program will run one cycle with the gripper arm

INTERRUPTS IN MAINPROGRAM

EXTERNAL INTERRUPT 6

This interrupt is connected to switch 2(SW2) on the STK600. This is done simulate a maintenance cover being opened or if an emergency stop button being pushed. This interrupts end the run cycle and stops the feeding mechanism motor.

COUNTER0, 8 BIT B COMAPRATOR

This interrupt controls the timing of when the holder releases the thread. When the gripper is moving backwards, the interrupt changes the "go_for_hold" variable. When this variable is one, the idle down function enable the holder/cutter motor.

COUNTER0, 8 BIT A COMPARATOR

This is used as a safety function. When the gripper approaches one of endpoints, this interrupts sets the speed very low. This ensures that the speed of the gripper will be reduced, before the brake is enabled.

ANALOG COMPARATOR

This interrupt is triggered if the weft sensor detects two or more threads moving. If this happens, the running cycle stops and the motor for the feeding mechanism are stopped. And a error is indicated with the variable “error1”.

RUN FEEDING MOTOR

The regulation of the feeding mechanism for the gripper arm is done by regulating the speed reference to the motor driver and keeping count of the pulses. Since the ATmega128RFA1 don’t have analog outputs, an external parallel DAC is controlled by Port B.

Variables used in regulation and defined as (all are “int”):

- **idle_state:**
  This is a variable used to indicate different stats when the motor is idling down.

The regulation is done in the "Run_FeedingMotor.c" and this includes the following functions:

- **enable_brake:**
  This enables the motor brake, stopping the motor. Enabling the brake is done by setting pin 4 on Port D high, only pin 4 is changed.
- **disable_brake:**
  This disables the motor brake, stopping the motor. Disabling the brake is done by setting pin 4 on Port D low, only pin 4 is changed.
- **set_speed_wDAC:**
  This function sets a new value to Port B, enables the DAC so that the new value is written and sets the DAC back in latched mode.
- **set_portB:**
  Port B is connected to DAC inputs, LSB to MSB. Pin 0 is the LSB and pin 7 is the MSB. The function sets a value to the port equal to the "int" sent to the function, this has to be defined between 0 and 255. The DAC won't change its output until "write_DAC" is run.
- **hold_DAC:**
  This function is setting pin 5 on Port D high, only pin 5 is changed. By setting pin 5 high, the DAC is set to "latched" mode. This means that if the input data is changed, the output data will stay the same.
- **write_DAC:**
  This function is setting pin 5 on Port D low, only pin 5 is changed. By setting pin 5 low, the DAC is set to "transparent" mode. When in "transparent" mode, the input data values is written to output.
- **enable_motor_forwards:**
  This function is setting pin 0 high and pin 1 high on Port D, only pin 0 and pin 1 is changed. Pin 0 is connected to enable on the motor driver, setting this pin low enables the motor. Pin 1 is connected to F/R on the motor driver, which determines the rotational direction of the motor. By setting this pin high the motor rotates counter clockwise (viewed from the front), propelling the gripper arm forwards.

- **enable_motor_backwards:**

  This function is setting pin 0 high and pin 1 low on Port D, only pin 0 and pin 1 is changed. Pin 0 is connected to enable on the motor driver, setting this pin low enables the motor. Pin 1 is connected to F/R on the motor driver, which determines the rotational direction of the motor. By setting this pin low, the motor rotates clockwise (viewed from the front), propelling the gripper arm backwards.
- **error1_occured:**

  This function can be used if an error occurs and the motor stops, for example if the emergency stop button I pushed or if the gripper grabs two threads. This function calculates were the motor has stopped in regards to the starting position. It then runs the motor slowly backwards until the motor reach the start position again.
- **accelerate:**

  This function accelerates the motor up to a given number of pulses. How much the motor will accelerate depends on how much "a" increments and how much delay there is. While the motor accelerates, the DAC is in transparent mode, writing new values to the output continuously. Although we can control the speed reference we cannot control the torque of the motor. We hope that by increasing the voltage reference slowly will result in smaller steps for the PI regulator, resulting in lower currents/torque to achieve reference speed.
- **idle_down:**

  When the motor is done accelerating, the speed has to be idled down again to least possible speed. Ideally the gripper has to be at its lowest speed a couple pulses before each end point. The gripper has to travel at low speed in order to stop as fast as possible. It is not possible to travel at high speeds and then set a very low speed, this result in a huge difference between the actual speed and the speed reference. Tests have shown that the PI regulator in the motor controller then will reduce the power to almost nothing in order to match the speed reference. If the difference between the speed reference and the actual speed is too big and the reference is set at a very low voltage, the motor will stop completely before starting again. This is very time consuming and this will increase the total cycle time.

- **run_cycle:**
  The run cycle function controls the feeding mechanism motor when it running backwards and forwards. This function is controlling the motor, when the thread check is done and when the motor for the cutter/holder and thread arm is going to be enabled. All of this uses the feeding mechanism motor pulse output (TCNT0) to time when the different action is executed. The run cycle can be stopped anywhere by setting the run variable as 0. If this is done without in a state where the motor is accelerating or running at constant speed the motor has to be disabled or the speed reference set to 0.

8 BIT COUNTER VS 16 BIT COUNTER

The 8 bit hardware counter can only handle 255 pulses. The number of pulses will be larger than this on the medium sizes and largest TC2. Although the 16 bit counter could store more than 255 pulses and more than enough for the two other types, this could corrupt a count pulse when accessing the 16 bit counter value. This described in more detail in the ATmega data sheet page 248 – 249[5]. Our solution suggestion is to use the Overflow interrupt which triggers when the count reaches 255. This interrupt is shown in our application. By adding 255 to a counter variable when the overflow you can instead compare the value by writing TCNT0 + counter. The 8 bit counter value is accessible through the 8 bit data bus.

SERIAL COMMUNICATION

As the Faulhaber communicates by serial, the master, the Atmega128rf1, has to use serial to communicate with the Faulhaber. The ATmega has inbuilt registers for the handling of Universal Asynchronous Receiver Transceiver (called UART, or USART for synchronous communication). When the signal is high, that equals a zero.

The baud rate that is going to be used here is 9600. This has to be set in the UBRRnx register. The value that has been imported is fetched from the Atmega128fr1 datasheet p367, table 23-15. The value fetched is 51 (called “baud_rate_serial” in the code) that we import into UBRR1H and UBRR1L.
UBRR1H contains the 4 highest bits and UBRR1L contains the lowest 8. After the baud rate has been imported to these registers, we can activate the UART. This is done by setting bit 3

and 4 in the “Control and Status register B” (UCSR1B). Bit 3 is for activation of the transceiver and bit 4 for the receiver. Will also set bit 7 that activated the interrupt when the receive buffer (UDR1) has been filled. I.e. not, set to zero. Now the UART is activated and we need to set the configuration for the communication. From the Faulhaber datasheet, we get that the controller works with 1 stop bit, 8 bit data and no parity bit. This is the default setting in the “Control and Status Register C” (UCSR1C), and therefore does not need any more settings. For easier understanding of the code, most registers and bits has been renamed. The definition header file is called “Serial_definitions.h”. This is done for easier reading of the program and what registers that is being manipulated.

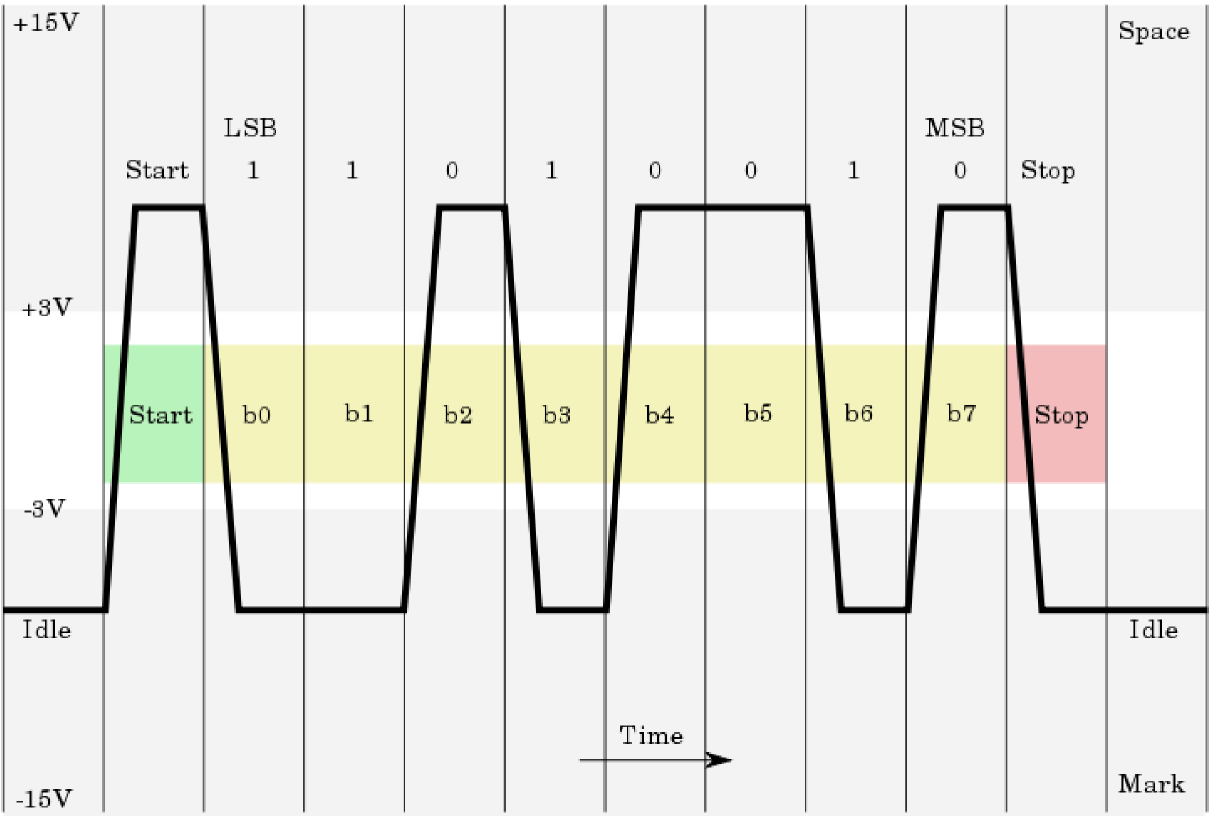

Figure 28: Serial communication example [6]

The figure above shows a transmission over the serial, with the start bit, the data and a stop bit. The start bit is always high and stop bit always low. In this case the sent data here is “1001011”, since the serial starts with bit 0. So the sent data here is 75 in value or the letter “K” from the ASCII table. This means that we only can send one letter at the time.

The code for initializing the UART:

```
void initiate_serial(void){
	//setting baud rate for transmitting/receiving
	Baud_prescale_8bitregister_high = (Baud_prescaler>>8);
	Baud_prescale_8bitregister_low = (Baud_prescaler);
	//setting 8 data bits, 1 stop bit and no parity
	Status_Control_register_C = (0<<UART_mode_highbit) | (0<<UART_mode_lowbit) |
	(0<<UART_pairity_highbit) | (0<<UART_pairity_lowbit) | (0<<UART_stop_bits) |
	(1<<UART_data_length_highbit) | (1<<UART_data_length_lowbit);
	// enable the transceiver and receiver
	Status_Control_register_B =
	(1<<UART_8bit_receive_registrer_full_interrupt_enable) |
	(0<<UART_8bit_dataregister_empty_interrupt_enable) | (1<<UART_receiver_enable)
	| (1<<UART_transceiver_enable);
	//deactivating double serial speed
	Status_Control_register_A = (0<<Double_UART_speed);
	sei();			// enable global interrupts
}
```

As seen from the code "`(Baud_prescaler>>8);`" moves the bits on the variable 8 spaces to the right, before moving it into the Baud_prescale_8bitregister-high/UBRR1H register. As the code above show, there is much registry writing, the reason for this is to guarantee a functional serial. Many of the bits are by default the value that are being set by the program, but is done to be sure.

Now the UART has been set up, the main issue now is the hardware lines between the Faulhaber and the Atmega128RFA1. As the Faulhaber works on serial by RS-232 connection, that uses up to ±15v and the ATmega uses 0-5v. Then it is very handy that the STK-600 has a level-shifter and a RS-232 connector.

The code for sending over the UART is as follows:

```
void send_data(unsigned char data_send){
	//waitng for buffer to be clear
	while ((Status_Control_register_A & (1<<UART_8bit_dataregister_empty))==0);
	//puts data into UDRE1 register, to be sent
	UART_8bit_dataregister=data_send;
}
```

Here the while is in place for checking if the buffer (UART_8bit_dataregister_empty/UDR1) is empty, and if not, it waits. When the buffer is empty, the desired message/command is placed into the Data register (UART_8bit_dataregister_empty /UDR1) and bit 5 in Control and Status register A is set, and hence hindering anymore information to be sent before the completion of the sending of the previous command/message.

The ATmega have to be able to receive data, this is done by the interrupt vector and a prototype (bit 7 in UCSR1B activates it). The interrupt vector is UART_8bit_registrer_full_interrupt /USART1_RX_vect and is defined by:

```
ISR(UART_8bit_register_full_interrupt)

{

	recieved=datareceived();

}
```

```
unsigned char datareceived(void){
	//waiting for data to be received
	while ( (Status_Control_register_A & (1<<UART_receive_complete))==0 );
	//importing data to string and return it
	return UART_8bit_dataregister;
}
```

Here the while waits for the completion of the receiving of the data, then returns the UART_8bit_dataregister/UDR1 register.

During testing (T-30.A.89-E), some problems were discovered. The serial communication did not go as anticipated and several tests were done to identify the problems. First off the cable was tested, and then the serial was scoped. The cable was correct, but the serials timing were off. The clock on the ATmega was checked and found correct, so the problem was with the scalar (the value in the UBRRnx registers were wrong). Therefore, a test code was developed for finding the correct value. The functional value was determined to be 100. But after a reconfiguration of the clock prescale registers for the ATmega128RFA1, the prescaler of 51 were used (Scaling set to 1).

As this serial "driver" is not the main program, it has been moved to a supplementary c file. The main program can from there send the required commands. The files is at the moment named "Serial.c" and can be broken down to 3 parts:

- Initialize the serial and controller (Faulhaber MCBL 2805)
- Send data over serial
- Receive data over serial

This program is written for 1 controller on the serial, but has been written to easily implement more controllers on the serial. This is done by setting node number (0-255) on the controller and then adds the node number before the command. i.e. "1JMP2" for "JMP2" on controller with node address 1.

Then the controller has to be set up, done by the following code;

```
void initiate_controller(void){

        send_data('E');
        send_data('N');
        send_data('P');
        send_data('R');
        send_data('O');
        send_data('G');
        end_trans();
        Send_data('M');
        end_trans();
}
```

The method "Send_data" sends the data over serial. The sent data here is:

- ENPROG enables the program on the Faulhabers
- M activates motion control

As seen over, the method “Send_data” sends the data over an activated serial, this is done fairly easy:

```
voidSend_data(unsignedchar data_send){
	//waitng for buffer to be clear
	while((Status_Control_register_A&(1<<UART_8bit_dataregister_empty))==0);
	//puts data into UDRE1 register, to be sent
	UART_8bit_dataregister=data_send;
}
```

This method does simply waits for the flag and the register to complete previous tasks, before importing new data to the Uart8bit data register, and then the ATmega sends the imported data soon as possible. This method can only send one character at the time, this means if we want to send “hello”, we have to send single characters to this method and end with a carriage return;

```
void end_trans(void){
	while((Status_Control_register_A&(1<<UART_8bit_dataregister_empty))==0);
	UART_8bit_dataregister=Carry_return;
}
```

Carry_return is defined by 0x0D, given by the ASCII table. This is like the “enter” key.

The last primary method is receiving of data, and looks very similar to “Send data”, but returns data instead of sending.

```
unsigned char datareceived(void){
	//waiting for data to be received
	while((Status_Control_register_A&(1<<UART_receive_complete))==0);
	//importing data to char and return it
	Return UART_8bit_dataregister;
}
```

This method also waits, but waits for the receiving to be completed, then returns the data. This method has the same limitations as "Send_data", one character at the time. There will also be received a "carry return" at the end, but this will be ignored by the rest of the program.

The functional part of the program is divided into 2 functions, one for the extension ("go_forward") of the arm and one for the retraction ("go_backwards"). These two functions are just sending "JMP2" and "JMP3" over the serial. As stated, the controller will answer with a "p" when the motor has reached its destination.

CONFIGURATION

The configuration file handles of the configuration needed for our application. The configuration files sets up the registers and ports on the ATmega128RFA1. A description of these registers and ports and how we configure them and why, is described in the Technology document (D-00.A.17-EM).

MODULE 40: CASING

CLAMPS FOR COPPER RAILS

The module needs to be connected to the copper rails for electrical current. We have designed a type of clamp that can be used, although not with cable connection yet. This can be seen in Figure 29.The copper rails used on the TC2 are 3 x 20mm.

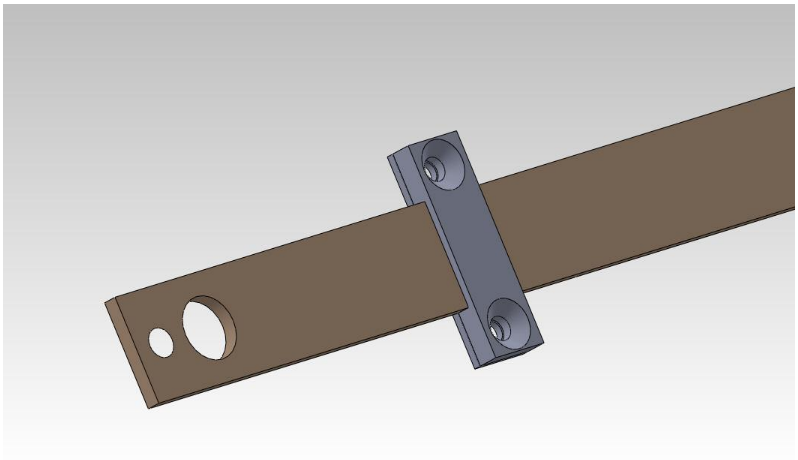

Figure 29: Clamp for rails

CHASSIS/BACK PLATE

PLAN B

Because we do not have time to develop a whole new casing from sheet metal, and still needs to test the system, we have made up a plan B. This new casing will be made out of plywood, which we will saw and mount together. This is easy to design and make with simple tools. Figure 30 shows a CAD-drawing of the chassis including the most important modules, thread selection system, spool holding system and gripper feeding mechanism.

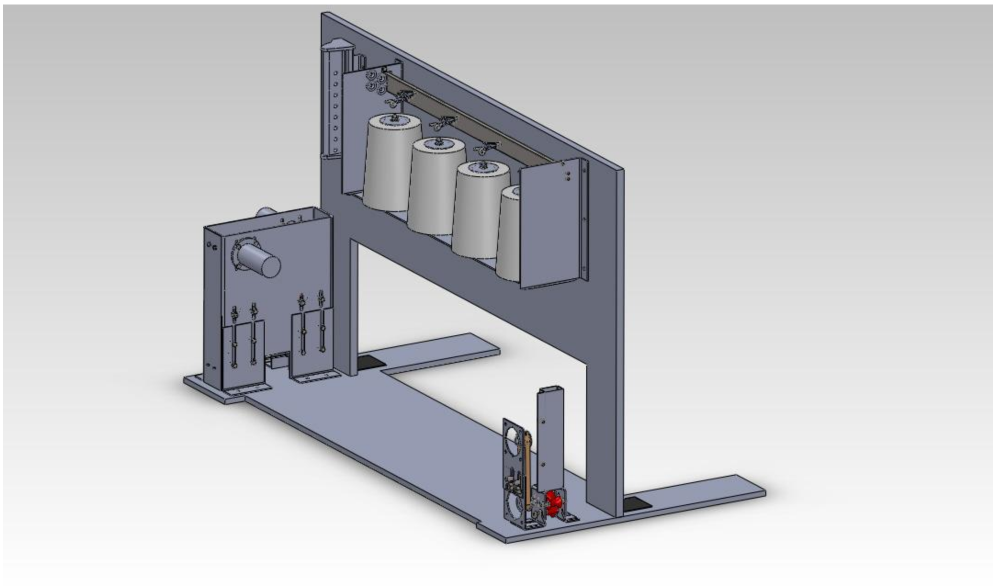

Figure 30: CAD drawing of new chassis incl. modules

The chassis is now finished, although it is possible that we need to modify the chassis slightly afterwards. Pictures from the assembly and painting can be seen in the document “Module building” (D-00.A.33-EM).The wood is 15mm thick plywood, which should be strong enough to support the modules.

ORIGINAL PLAN

The module needs to be fastened the chassis of the TC2, and we have to use the four existing fixing points for the front plate. The original front plate needs to be taken off before mounting the module, as well as the side panels. Figure 31 shows the chassis of the TC2 and the fixing points. The blue area is the surface in which the module will be mounted to. The red arrows show the locations of the 4 mounting holes.

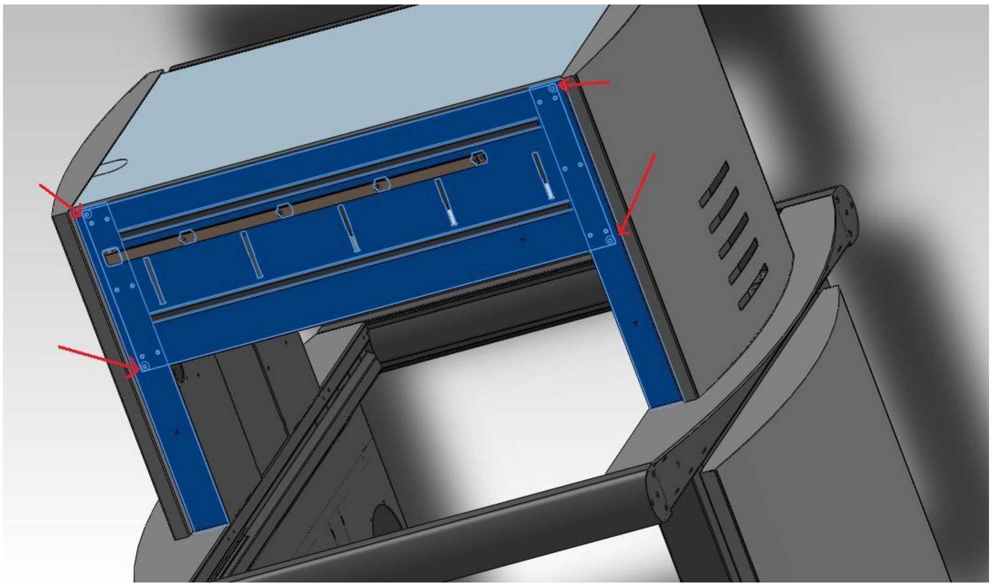

Figure 31: The TC2 and mounting holes

For designing the chassis, we thought of two different solutions: a single back plate or a twin plate chassis. The single back plate is meant to be fastened directly to the chassis of the TC2, and consists only of one plate that supports all the modules. A twin plate chassis is a chassis where the individual modules and the parts are mounted between two plates. The twin plate chassis can also be mounted directly to the chassis of the TC2. To make a decision; we made a table with pros and cons:

	Single back plate	Twin plate chassis
Pros	Easy to buckle Easy to mount parts Simple for prototype build	Strong construction Distributes forces Parts can be mounted with bolts
Cons	Weak construction Requires brackets welding/screwing Much weight/force on 4 bolts	Heavy Tight between plates Complicated to produce Requires high accuracy

Because this module only is a prototype and that we want to keep things simple, cheap and modifiable throughout the project, we were going for the single back plate solution.

Our idea is to mount every part and sub-module to a chassis or back plate. The brackets for the parts will either be fastened with screws or welded to the back plate. The whole casing will consist of two major parts: a back plate and a front casing. The front casing will be fastened to the back plate as the other parts, and will have doors to access the spool holding system. Figure 32shows a CAD-drawing of the back plate. It is designed based on the space we have been given, but is a bit higher because of the spool holding system. The back plate is designed to be buckled from one piece of 2.5mm thick sheet metal.

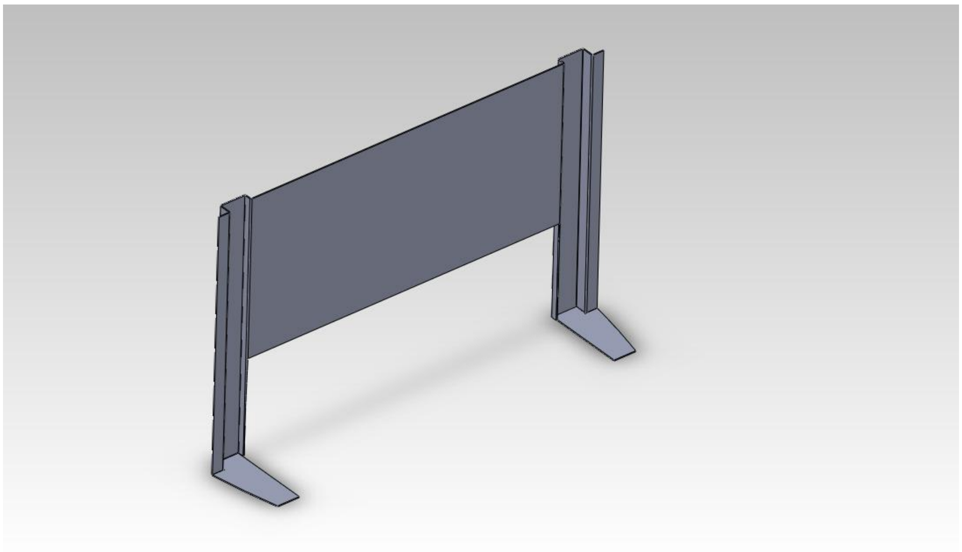

Figure 32: The back plate

We were a bit concerned about the back plate's ability to handle weight, but simple SolidWorks Simulation stress tests show that both the plate and our fastening bolts seem to cope with the forces and stresses.

The chassis development is behind schedule because of design of more critical parts and module. The chassis turns out to not fit properly either. If there is time at a later point, we will develop the chassis and casing more, but this is not planned.

SOURCES

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TECHNOLOGY DOCUMENT OF

“AUTOMATIC SHUTTLE CONTROL SYSTEM”

D-00.A.17-EM

Release 2.0

TRONRUD ENGINEERING AS

RELEASE NOTES

Date	Version	Description	Author
02.02.2012	0.1	- First draft	Eirik Nordstrand
09.02.2012	0.1.1	-Added more info sensors	Eirik Nordstrand
09.02.2012	0.2	- Moved discarded solutions to its own document	Eirik Nordstrand
10.02.2012	0.2.1	- Added more info on controller unit	Eirik Nordstrand
23.02.2012	0.3	Added text under chapter 23	Andreas Stustad
25.02.2012	0.4	Added text for Atmel	Eirik Nordstrand
06.03.2012	0.4.1	Added text for yarn sensor	Eirik Nordstrand
07.03.2012	0.4.2	Added text for interrupt and yarn sensor.	Eirik Nordstrand
07.03.2012	0.4.3	Deleted mechanical part chapter 23	Andreas Stustad
08.03.2012	0.4.4	Added some text for STK600	Eirik Nordstrand
08.03.2012	0.4.5	Added technology information about the feeding mechanism for gripper arm	Mats Strand Sætervik
08.03.2012	0.4.6	Added prototype for module 20 Added for original design	Andreas Vander Inge Ytre-Eide
09.03.2012	0.4.7	Edited figure references and updating tables and sources	Mats Strand Sætervik
12.03.2012	0.4.8	Added current design for module 20	Andreas Vander
13.03.2012	1.0	Removed prototype module 20 to discarded Added information for module 10 Added information for module 11 Added information for module 12 Finalized technology document 1.0	Andreas Vander Vazgen Karlsen Eirik Nordstrand
20.04.2012	1.1	Removed technology information for the speed regulator for the feeding mechanism for the gripper arm, moved to Discarded_Design and analysis_D00B23EM	Mats Strand Sætervik
24.04.2012	1.1.1	Added information, Faulhaber MCBL2805	Inge Ytre-Eide
02.05.2012	1.2	Updated technology document, regarding input from thread sensor, module 23.	Eirik Nordstrand
04.05.2012	1.3	Added information module 14	Mats Strand Sætervik
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ABOUT THIS DOCUMENT

This document contains our research for the different modules at the loom. It describes the technical solutions we are working on now, in detail, and discusses advantages and disadvantages for these solutions.

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INTRODUCTION

This document contains research of the technical solutions in this project, both mechanical and electrical.

The document is divided into chapters pointing to the modules or sub-assemblies in the system or prototype we are producing. As mentioned in earlier documents, our module consists of 3 main modules: thread/spool holding- and feeding mechanism, thread selection and Gripper/gripper arm feeding. All these modules have their own technical solution, both electrical and mechanical.

A general description of what kind of information is available in each module:

Thread/spool holding system: The electrical solution in this module is regarding the g3w weft sensor, and how the microcontroller uses this sensor to indicate when there are no more thread on the spools or if the gripper accidently grabbed multiple threads.

Thread selection system: Built in one module, controlled by two Faulhaber MCBL 2805. One controls the motor for the arm, the other controls the motor for the holder/cutter. Communicates by serial with the ATmega.

Gripper/gripper arm feeding:

- Calculations of forces, different motor types and how they would perform.
- Description of the motor driver
- General description of DC and BLDC motors
- Pulse accuracy

PCB:

- Description and calculations of electrical hardware mounted on the PCB
- Description and calculations for the voltage regulator

Controller unit:

- Descriptions of the ATmega128RFA1.
- Description of how our registers are configured and why.
- Information about the STK600.

Mechanical design: All mechanical modules are based on sheet metal. Sheet metal is metal plates between 0.5 to 12mm thick. Moss Jern- og Stanseindustri produced these parts for us. The parts were first cut out in a stamping machine or by a laser cutter before being bent to shape either in a machine or by hand.

MECHANICAL SOLUTION

The gripper contains three parts as described in Design and analysis doc. (D-00.A.18-EM_07)

- Top part.
- Bottom part.
- Hook.

The top and bottom part are going to be produced of plastic. The material that is chosen for this is Polyoxymethylene, also called POM-C.

The reason why we are using this material is because:

- It is cheap in our case, where amount of material is minimal.
- POM is a material with a very low friction coefficient, high heat resistance and high abrasion resistance which in our case is desirable.
- It is a free-cutting material, which means that it is an easy machining material.
- It has excellent dimensional stability.
- It is a material with high impact resistance.

Large components machined of POM can be dimensional unstable. The components we are going to machine are quite small and will not suffer because of their size.

Data sheet and more information about this material can be found here[2].

Both parts can be machined by a CNC machine (Computer Numerical Control) which is a machine tool that uses programs to automatically execute a series of machining operations[3].

Operations can also be done by simpler machines like lathe and miller.

Simpler machines require knowledge to different variables of machining process such as angles of the cutting tool, speed, feeding speed etc. Some of those data for this material can be found here.[4] The hook can be produced by folding a sheet metal plate made of steel into desirable shape. Attachment hole for the hook is drilled into the sheet metal plate before it is folded. The whole gripper is illustrated below in Figure 1.

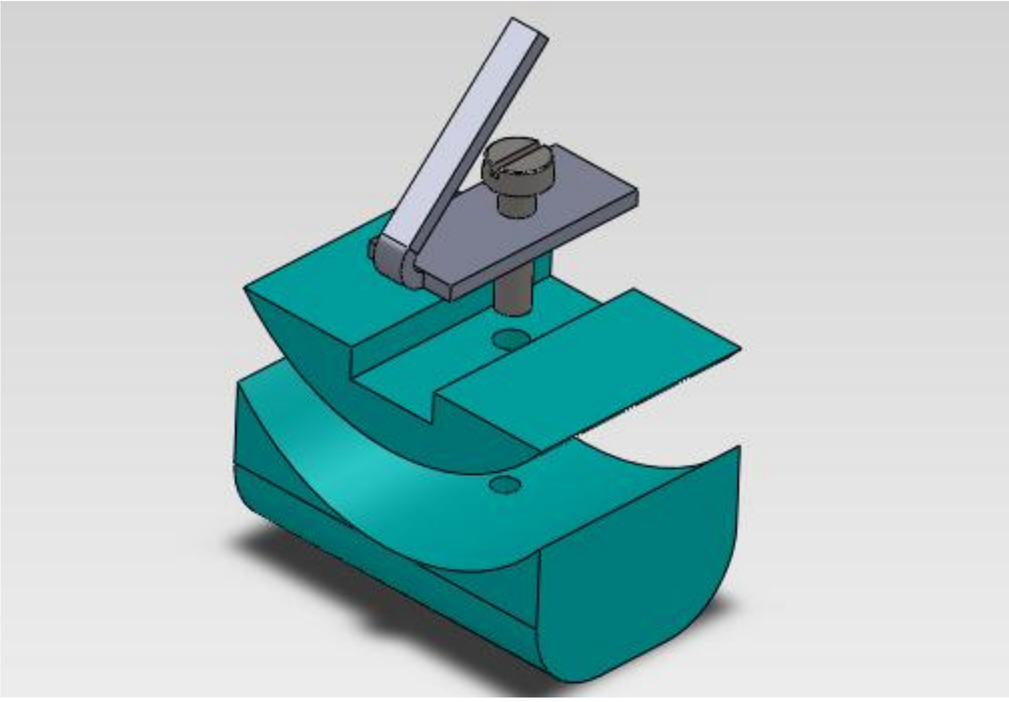

Figure 1: Gripper

MODULE 11: GRIPPER ARM

MECHANICAL SOLUTION

The gripper arm is an existing measuring tape made of alloy steel, with dimensions as illustrated in Figure 2.

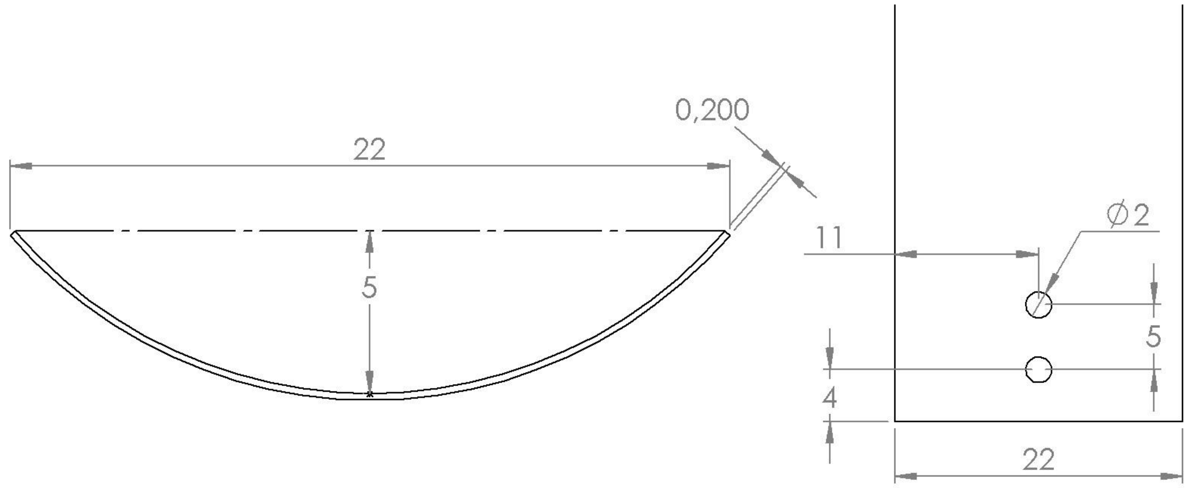

Figure 2: Measuring tape dimensions

There are existing holes on the end of measuring tape with a diameter of 2mm, which are going to be used as attachment points for the gripper.

MODULE 12: FEEDING MECHANISM FOR GRIPPER ARM

MECHANICAL SOLUTION

All frames of the feeding mechanism are made of sheet metal Steel DC 01 Am plate which is folded into the desirable shape. Machine press makes all desirable cavities in the sheet metal plate in advance. Corner frame of the feeding mechanism before and after folding is illustrated below in Figure 3.

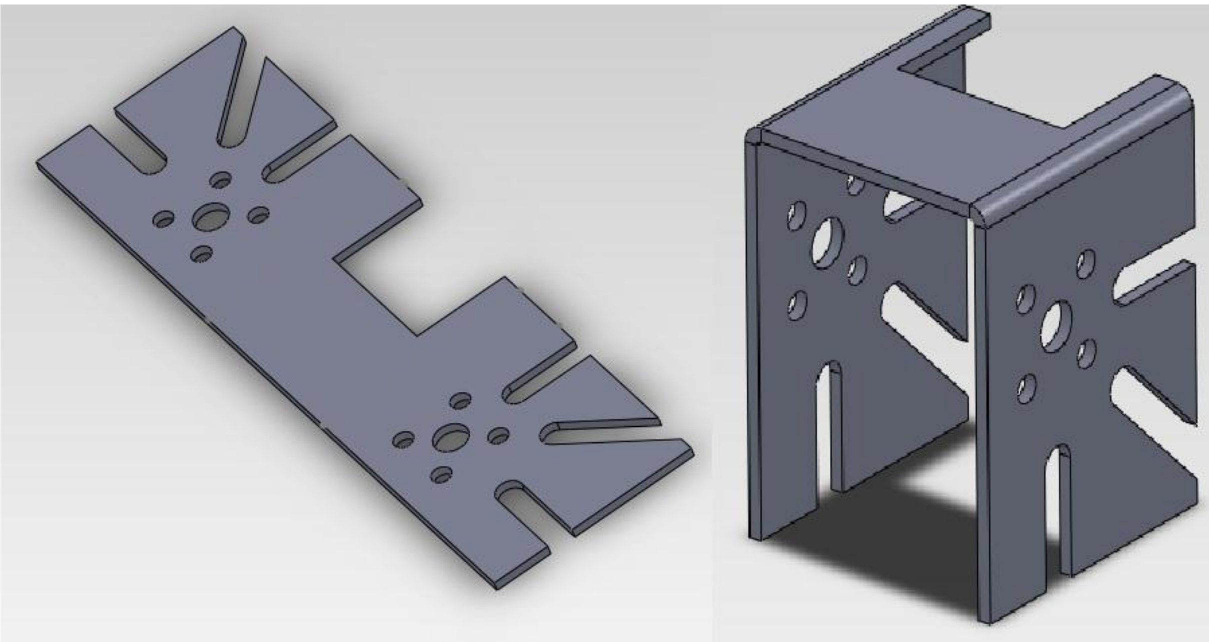

Figure 3: Corner frame before and after folding

Every wheel includes two bearings. There are three types of support wheels with in this module. Every shaft through the support wheel is made of alloy steel with threads on both ends. Threaded ends make it possible to lock shafts in desired position by placing a nut on each side of the frame wall. These threads can be machined to M5 standard by CNC machine or simpler machine like lathe[3]. There are two Seeger ring slides on each support wheel shaft. Seeger rings makes it possible to lock the wheel in desired position. The whole support wheel construction is illustrated below in Figure 4.

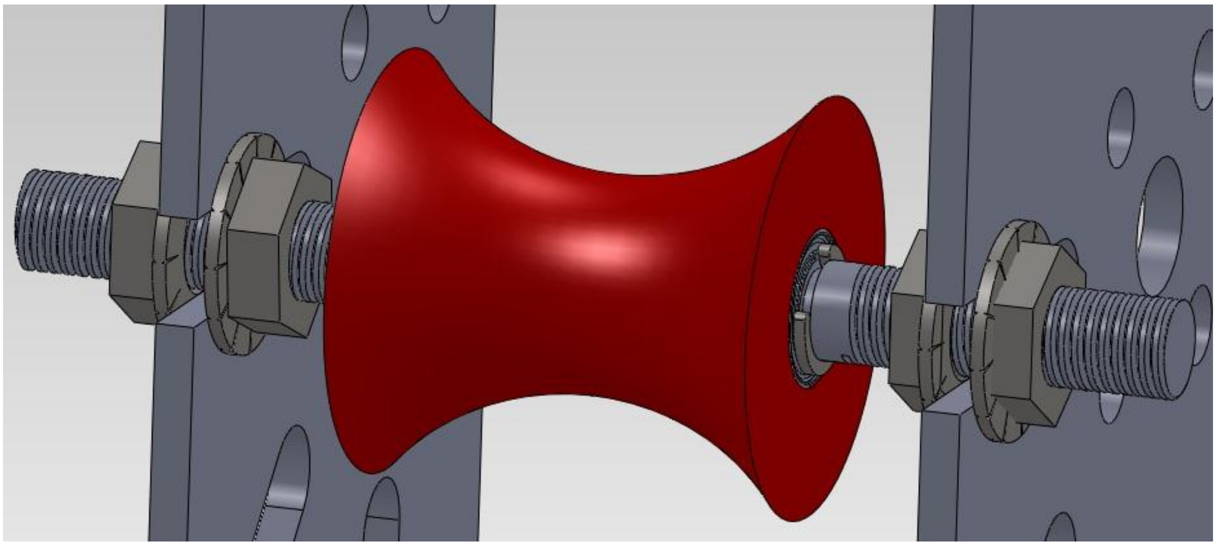

Figure 4: Support wheel construction

Support wheels are going to be produced of plastic. The specific material for these components is going to be POM-C. As mentioned in chapter “Module 10 Gripper” POM has a low friction coefficient, is a free cutting material and has excellent dimensional stability.

The drive wheel of the feeding mechanism has a little bit different construction. The rubber wheel is attached to the serrated shaft with a contact or two-component glue. Since it is a drive wheel, the shaft has to rotate. By using two bearing houses, it is possible to store the drive wheel shaft at the same time as it can rotate. There are four M3 standard threaded holes in each bearing house. Those bearing houses are attached to the corner frame with four standard M3 bolts. The whole drive wheel construction is illustrated below in Figure 5.

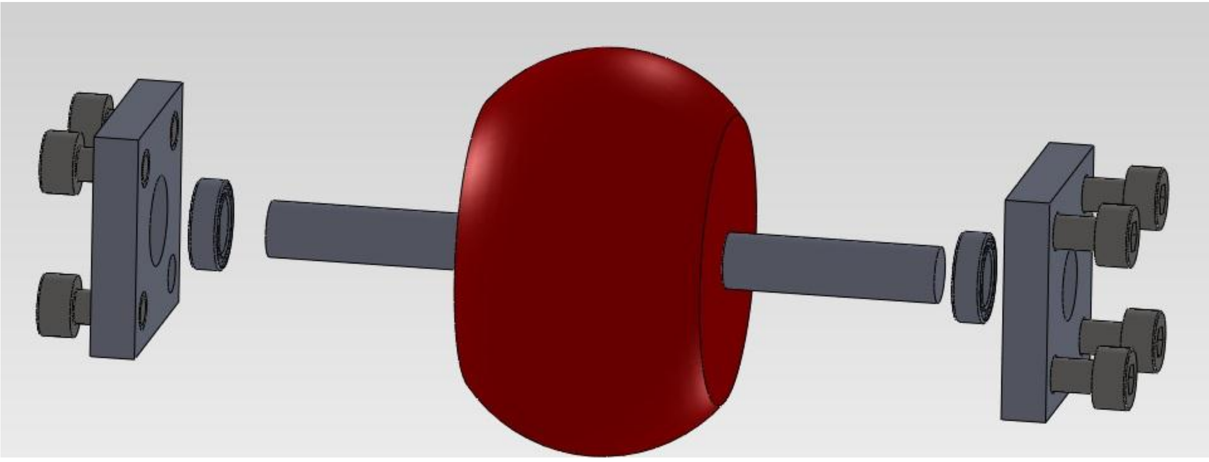

Figure 5: Drive wheel construction

The actual wheel that is attached to the drive shaft is going to be produced of polyurethane, also called PUR. More specific material that is going to be used is “PUR Shore 90 A EM”. This material has desired properties like:

- It has high friction coefficient.
- It has high durability.

PUR can have difficult machining process since it is a ductile material. By freezing it, the material gets stiffer and machining process can be done easier. Data and variables for machining this material can be found here[4].

The bearings we are using are similar for each wheel and are delivered by SKF.

It is W 627/5-2Z bearing. Data sheet for this bearing can be found below in Figure 6.[5]

Principal dimensions			Basic load ratings		Fatigue load limit	Speed ratings		Mass	Designation
			dynamic	static		Reference speed	Limiting speed		
d	D	B	C	C_0	P_u				
mm			kN		kN	r/min		kg	-
5	8	2,5	0,14	0,057	0,0025	140000	70000	0,00034	W 627/5-2Z

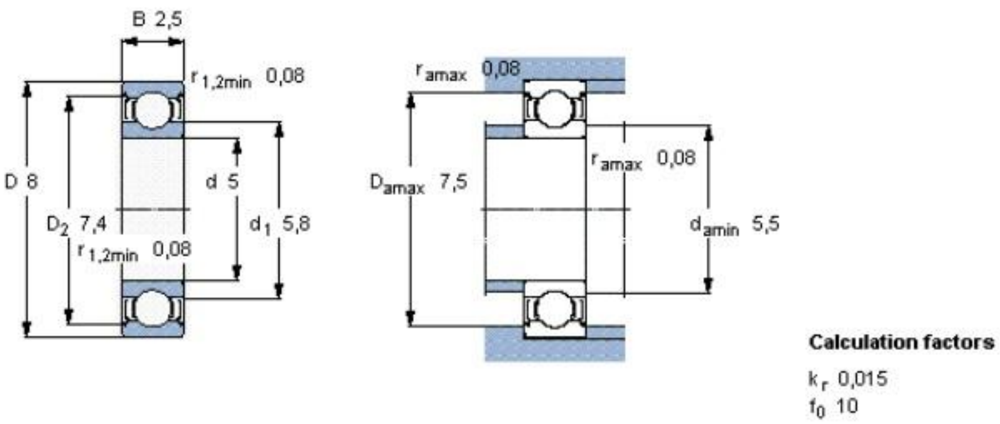

Figure 6: W 627/5-2Z bearing data sheet

Power transmission from the motor to drive shaft is going to be directly or through belt and pulleys. The reason why belt and pulleys solution is used is to have possibility to change ratio. Used belt and pulleys are existing parts from SDP-SI and are listed below:

Belt	
Part Number	A 6B 3M060095
Unit	Metric
Belt Type	Single Sided
Pitch	5.08 mm (XL)
No. Of Grooves	60
Belt Width	9.5 mm
Material	Polyurethane
Tension Member(cords)	Kevlar
Pitch Length	305.00 mm

Pulley A	
Part Number	A 6Z 3M15DF09506
Unit	Metric
Pitch	5.08 mm (XL)
No. Of Grooves	15
Material	Polycarbonate
Belt Width	9.5 mm
Bore Size	6.00 mm
Bore Configuration	Aluminum Insert
Flange Configuration	2 Flanges / With Hub
Pitch Diameter	24.30 mm
Outside Diameter	23.70 mm
Overall Length	20.60 mm

Pulley B	
Part Number	A 6A 3M15DF09510
Unit	Metric
Pitch	5.08 mm (XL)
No. Of Grooves	15
Material	Aluminum Alloy
Belt Width	9.50 mm
Bore Size	10.00 mm
Flange & Hub Configuration	2 Flanges/With Hub
Pitch Diameter	24.30 mm
Outside Diameter	23.70 mm
Overall Length	20.60 mm
Hub Diameter	16.00 mm

The main reason why those components are chosen is because they fit into prototype.

SPEED REGULATOR

Speed controller Fullingmotor24ZWSK30-B-806:

The datasheet for the motor driver can be found here [6].

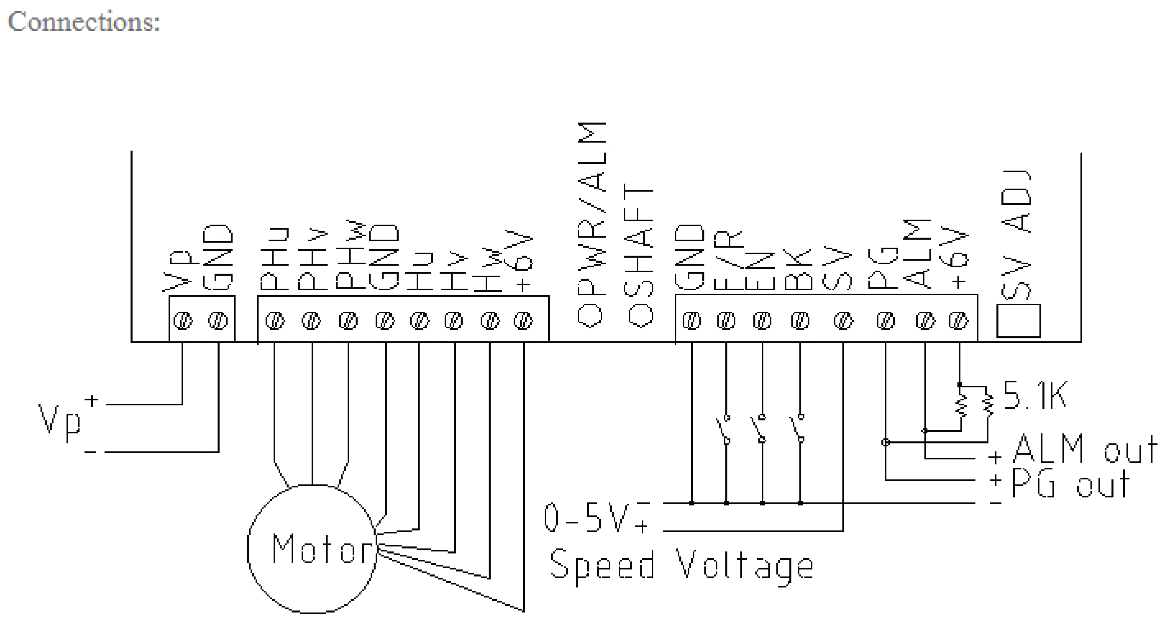

Figure 7: 24ZWSK30-B-806 connections[6]

Explanation of control inputs:

- F/R: Direction control bit. Switching between high and low value sets the rotational direction of the motor.
- PG: Speed output pulses, 24 pulses per revolution with a motor with 8 poles. This is an open collector output.
- SV: Speed input voltage. Sets the motors speed with an analog 0 to 5 V signal.
- BK: Brake control bit. This enables the brake for the BLDC.
- Vp: Voltage supply input, 24 V.
- PHu – PHW: Power supply for the different armature windings.
- Hu – Hw: Hall sensor output:
- +6V: Supply voltage output, 6 V.

The input resistances aren't mentioned in the datasheet but we have measured one of them:

SV: Approximately 100 kΩ.

PI speed close loop control:

The control mode for this controller is PI speed close-loop control. This basically means that the controller will try to hold the set point speed (given by SV) and compensate if more torque load is added or lost. The controller compensates by regulating the current. It continuously regulates the speed by comparing the speed reference with the speed feedback, by negative feedback control.

Open collector output:

An open collector output enables to use whichever voltage supply we want.

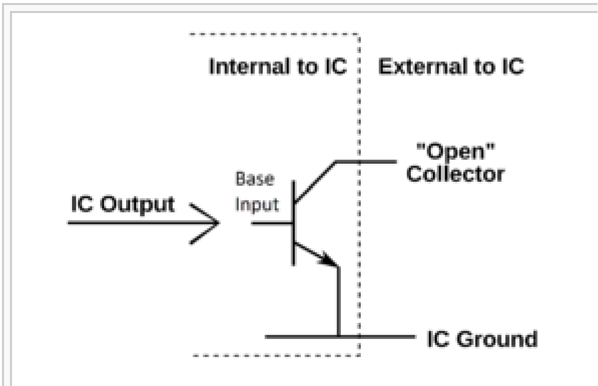

Figure 8: Open collector output[7]

PULSE CALCULATIONS AND ACCURACY

We don't want the speed to be regulated by the resolution of the pulses provided by the PG output on the controller by only reading the pulses. First we can calculate the number of pulses half a cycle will require:

The largest TC-2:

Accuracy of the position of the pulley wheel is given by one rotation divide by the resolution:

$$\frac{360°}{24} = 15°\ or\ \frac{2\pi}{24} = 0{,}2618\ rad$$

Our travel distance is 0.85 meters (850 mm) and the pulley wheel radius is 18 mm. The number of pulses one way, is given by the circumference and the total distance:

$$2 \cdot \pi \cdot 18\, mm = 113{,}0973\, mm$$

$$\frac{850\, mm}{113{,}0973\, mm} = 7{,}5157\, revolutions$$

$$(7{,}5157 \cdot 24) \approx 180\, pulses\ one\ way$$

Accuracy if we assume worst case, i.e. if the pulley is 7,5° from a counting edge, the difference between the actual position and the last pulse is approximately:

$$\frac{113{,}0973\, mm}{24} = 4{,}712\, mm$$

Speed and position regulators are used to regulate DC motors. The dynamics equations for the general DC motor is given by[8]:

$$L\frac{di}{d\omega} = -Ri(t) - K_b\omega(t) + v(t)$$

$$J\frac{d\omega}{dt} = -f\omega(t) + K_T i(t) - \tau_L$$

$$\frac{d\theta}{dt} = \omega(t)$$

Where:

$$L = Inductance\ (H)$$

$$J = Rotor\ inertia\ (Kgm^2)$$

$$R = Resistance\ (Ohm)$$

$$K_T = Torque\ constant\ (\frac{Nm}{A})$$

$$K_b = Back\ EMF\ constant\ \left(\frac{V}{rpm}\right)$$

$$\tau_L = Torque\ Load\ (Nm)$$

$$f = friction\ \text{coefficient}$$

$$\omega(t) = \text{Rotational speed as a function of time}\ \left(\frac{\text{rad}}{\text{s}}\right)$$

$$i(t) = Current\ as\ a\ function\ of\ time(\text{A})$$

$$v(t) = Voltage\ as\ a\ function\ of\ time(\text{V})$$

Then the speed change of the DC motor is given by:

$$\tau_m - \tau_L - f\omega_R = J\frac{d\omega_R}{dt}$$

Acceleration of the DC motor in relation to load and available torque:

$$\tau_m = J\frac{d\omega_R}{dt} + f\omega_R - \tau_L$$

In our project and our prototype we are using a 24 V BLDC motor with 3 phase and 8 poles. BLDC or brushless DC motor is the general used term. In theoretical descriptions, this is referred as PM synchronous machine[8]. The magnetic fields are uniformly disturbed in the air, when the motor is running at constant speed it creates a back emf with a trapezoidal shape in time.

A 3 phase BLDC motor contains three sets of windings. Each current has its own current designated i_{S1}, i_{S2} and i_{S3}. Figure 9 illustrates a 3 phase BLDC motor with the location of the windings.

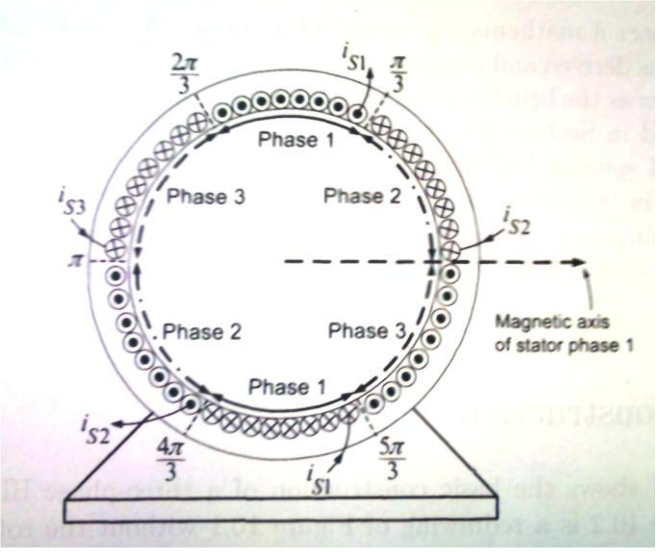

Figure 9: Illustrations of a 3 phase BLDC[8]

Figure 10 illustrates the back emf, currents and power waveforms for each winding of a BLDC motor. The figure illustrated how the currents, power output and back emf behaves in relation to the motor position

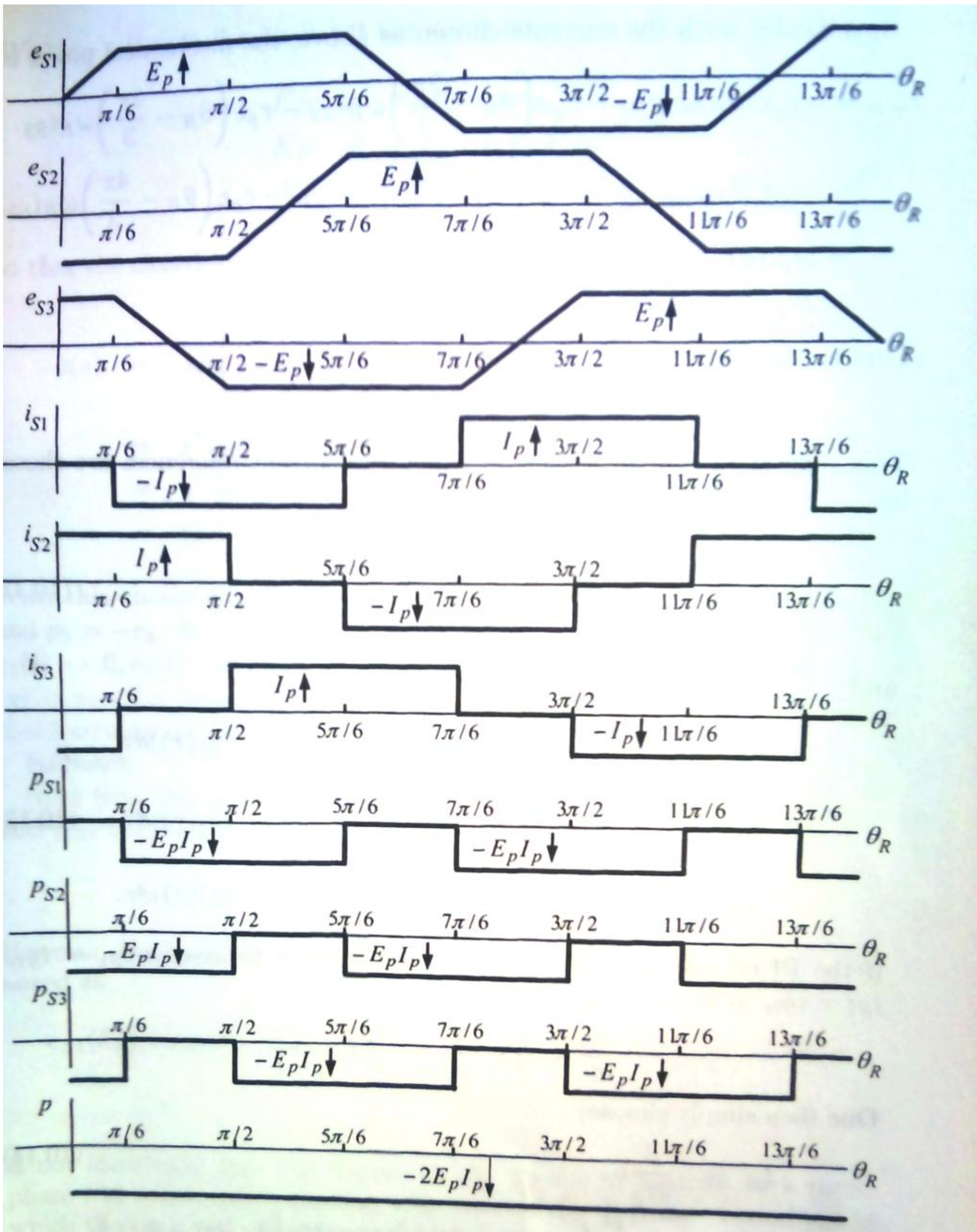

Figure 10: Back emf, currents and power waveforms in BLDC[8]

The motor controller main task is to control i_{S1}, i_{S2} and i_{S3} in respect to the motor position. Usually the motor is equipped with hall sensors, which can be used to detect the motor position. But it’s also possible to calculate the motor position by using the back emf. Our motor is equipped with hall sensors and the motor controller uses these to get the motor position.

The equation for the PI controller gain is given by[8]:

$$U_{S1} = K_P(i_{S1r} - i_{S1}) + K_I \int_0^t (i_{S1r}(\tau) - (i_{S1}(\tau))d\tau$$

This regulator compares the actual current with the reference current. The controller “forces” the current to be equal to the reference current. Different set up of these PI controllers determine their speed and their ability to handle load changes. The word “BLDC” often means a complete motor often equipped with optical or hall sensors and sometimes with an amplifier and controller integrated, its illustrated in Figure 11. It’s then possible to construct a PI controller that controls the supply control and uses the optical or hall sensor output for reference. Our motor has hall sensors, but does not have the control and amplifier function.

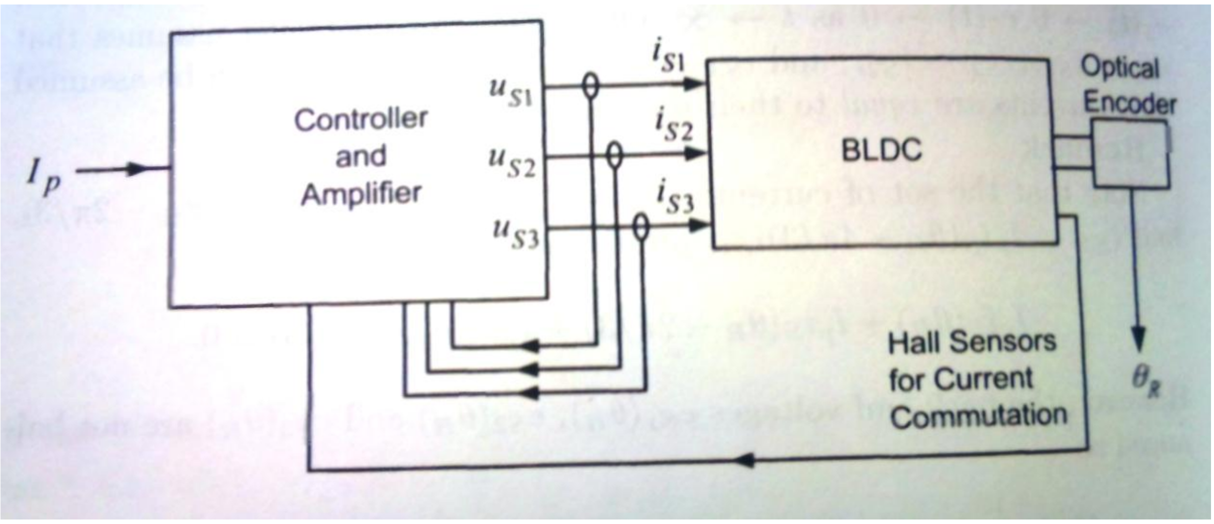

Figure 11: Block diagram of brushless DC motor[8]

To get a simple overview of what kind forces and acceleration around the gripper and gripper arm, we have developed a simple Excel [9]sheet. The sheet calculates different types of potential motor performance with regards to the forces working in the module.

The Excel sheet is called “Calculations_MotorAndTransmission” and can be found under the folder Attachments ->Feeding mechanism for gripper arm.

All of the data for the motors is taken from each motors' datasheet. These can also be found under Attachments->Feeding mechanism for gripper arm->Data Sheets motors.

In the Excel sheet the nominal torque of the engine is used to calculate developed push force and acceleration. In other words the torque is considered to be constant. This is not entirely correct, and will be corrected later when we simulate the system in Matlab[10].

The grey filled cells contain value that hasn’t been calculated, these can be changed.

All of the formulas for forces and speeds have been taken from [11].

Explanation of variables used in the Excel sheet and in this document, and Figure 12 illustrates where they contribute in the design:

$$T_M = Rated\ torque, motor$$

$$r_P = Radius\ of\ pulley\ wheel$$

$$r_F = Radius\ of\ free\ wheel$$

$$F_M = Max\ force\ possible\ by\ motor => T_M/r_P$$

$$F_a = Force\ that\ accelerates\ gripper\ and\ gripperarm$$

$$F_n = Applied\ pressure\ to\ pulley\ wheel$$

$$C_f = Friction\ coeffisient$$

$$F_f = Friction\ force => F_n * C_f$$

$$F_f = Friction\ force => F_n * C_f$$

$$C_r = Role\ resistance\ coeffisient$$

$$F_r = Role\ resistance => F_n * C_r$$

$$m_{G+GA} = Mass, Gripper\ and\ Gripperarm$$

$$a_T = Tangantial\ acceleration$$

$$F_C = Counter\ forces. Forces\ that\ acts\ againts\ the\ acceleration.$$

$$This\ can\ be\ neglected\ forces\ or\ a\ safety\ buffer.$$

$$I_F = Moment\ of\ inertia, free\ wheel$$

$$I_P = Moment\ of\ inertia, pulley\ wheel$$

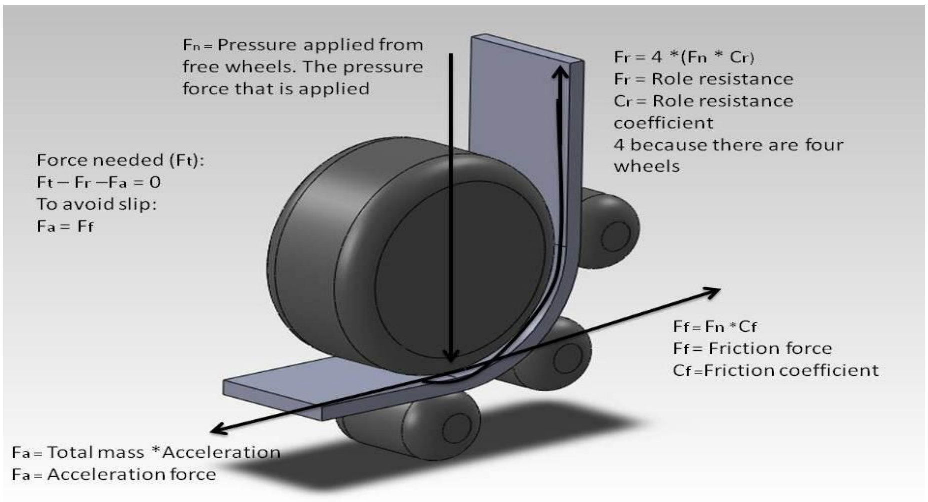

Figure 12: Pressure force and role resistance

$$F_a = F_f$$

$$Ff = F_M$$

There are three wheels that there can be applied force to improve grip. Some of them aren't placed at a direct angle towards the gripper arm movement. The equal applied force to improve grip. All of them aren't placed at a direct angle towards the gripper arm movement. The equal applied force to improve grip. All of them aren't placed at a direct angle towards the gripper arm movement. The equation that solves how much pressure that needs to be applied to avoid grip is:

$$F_M = F_n + (2 \cdot Fn \cdot \cos(22{,}5))$$

$$F_n = \frac{F_M}{(1 + (2 \cdot \cos(22{,}5)))}$$

$$F_r = F_n \cdot C_r \cdot 4$$

Figure 13 illustrates how the forces were interpreted.

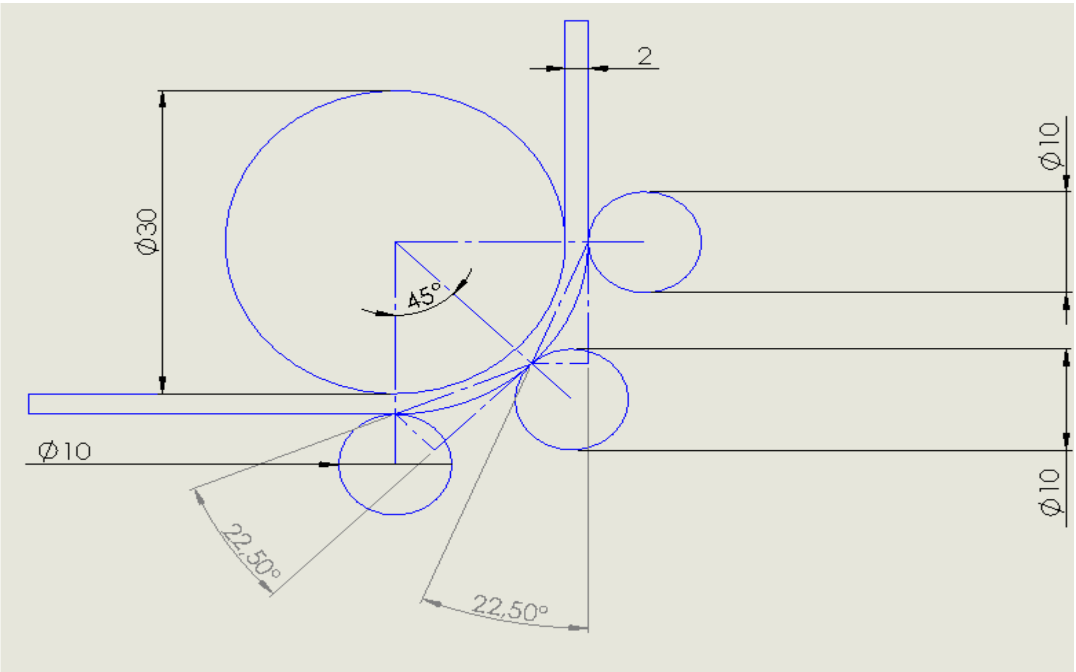

Figure 13: How each free wheel contributes to the linear motion

The acceleration equation is derived by:

$$\frac{T_M}{r_P} = \left(\frac{a_T \cdot r_P \cdot 2 \cdot I_P}{r_P}\right) + \left(\frac{a_T \cdot r_F \cdot 6 \cdot I_F}{r_F}\right) + (m_{G+GA} \cdot a_T) + F_r + F_C$$

$$F_M = (a_T \cdot 2 \cdot I_P) + (a_T \cdot 6 \cdot I_F) + (m_{G+GA} \cdot a_T) + F_r + F_C$$

$$F_M = a_T \cdot (2 \cdot I_P + 6 \cdot I_F + m_{G+GA}) + F_r + F_C$$

$$\frac{F_M - F_r - F_C}{(2 \cdot I_P + 6 \cdot I_F + m_{G+GA})} = a_T$$

This acceleration is withdrawn from the acceleration which is calculated from the force available to accelerate the gripper.

An example from the Excel sheet, which is calculations for the motor we use on the prototype:

ME060AS101 and ME060AS102

Type:	Brushless	
Producer:	Exmek	
Distributor:	OEM	
Price:		
Total length:	112	mm
Width:	61x61	mm

Motor specifications:

Supply voltage:	24	V
Rated power:	100,800	W
Nominal current:	4,200	A
Peak current:	12,600	A

Resistance:	0,45	Ohm
Inductance:	0,55	mH
	5,50E-04	H
Back EMF constant	5,6	V/krpm
Rotor inertia:	0,45	kgcm^2
	4,50E-05	kgm^2
Torque constant:		
Rated speed:	3000,000	RPM
Gripper arm top speed:	15,834	km/h
	4,398	m/s
Rated torque:	0,250	Nm
	17,857	N
Start torque:	0,750	Nm
Gear ratio:	1,000	
efficiency:	1,000	
	17,86	N
	3000	RPM
Gripper arm top speed:	15,834	km/h
	4,398	m/s
Forces:		
Each wheels needed friction force:	6,27	N
Pressure needed on each wheel:	12,541	N
Rolling resistance: (4 wheels)	2,508	N
Counter forces:	6,324	N

Acceleration: (Included loss to moment of inertia)	30,08	m/s^2

If we accelerate half the distance:

The widest TC-2:

Let the motor accelerate until:	0,900	m
Top speed:	4,398	m/s
	15,834	km/h
	3000,000	RPM
If top speed<Max RPM:		
Total travel time: (0,9 m)	0,000	s
Travel time: (1,8 m)	0,000	s
Travel time: (Both ways)	0,000	s
If top speed>Max RPM:		
Time to reach top speed:	0,146	s
Distance covered:	0,322	m
Time it takes to travel remaining distance:	0,132	s
Total travel time: (0,9 m)	0,278	s
Travel time: (1,8 m)	0,555	s
Travel time: (Both ways)	1,111	s

The narrowest TC-2:

Let the motor accelerate until:	0,550	m
Top speed:	4,398	m/s
	15,834	km/h
	3000,000	RPM
If top speed<Max RPM:		
Total travel time: (0,55 m)	0,000	s
Travel time: (1,1m)	0,000	s
Travel time: (Both ways)	0,000	s
If top speed>Max RPM:		
Time to reach top speed:	0,146	s
Distance covered:	0,322	m
Time it takes to travel remaining distance:	0,052	s
Total travel time: (0,9 m)	0,198	s
Travel time: (1,8 m)	0,396	s
Travel time: (Both ways)	0,793	s

DAC– AD558JNZ

AD558 datasheet can be accessed here[12].

DAC (Digital to analog converter) allows us to use digital outputs and turn them into an analog signal.

Use of DAC when VCC only is >0, requires rail-to-rail operation.

The AD558 is a complete 8- bit DAC capable of operating on a supply voltage range 4.5 -16.5 V.

The voltage output range can be set as 2.56 V or 10 V, with the use of outputs V_{OUT}, V_{OUT}SENSE A and V_{OUT}SELECT.

The resolution of the output is defined by the number of bits and the voltage output range. An 8 bit resolution DAC with range 0-10 V will give accuracy: $\frac{(10-0)}{2^8} = 0{,}0390625\ V$.

8 bit resolution DAC with range 0-2.56 V will give accuracy: $\frac{(2.56-0)}{2^8} = 0{,}01\ V$.

The best resolution and settling time will be achieved by using range 0-2.56 V. Since our motor controller uses 0-5 V inputs to set the speed, we will need a voltage follower to gain the signal by 2. To not compromise the performance (settling time) of the DAC, the voltage follower's slew rate has to be at least as fast as the DAC settling time. The settling time while using the 0-2.56 V range is typically 0.8 µs and maximum 1.5 µs. This is specified when the DAC is increasing its voltage. Negative-going steps are slower, but can be improved with an external pull-down.

We could also use a voltage divider to reduce the voltage by 2, but this would increase the settling time of the DAC and decrease the accuracy of the voltage output. By using a voltage gain instead of voltage dividing, we also get a higher tolerance difference in reference to VCC. If the range is set to 0-10 V the lowest acceptable supply voltage is 11.4 V, while the 0-2.56 V has 4.5 V.

The voltage output is set by the data input bits, from the least significant bit (LSB) to the most significant bit (MSB). The data inputs and control specifications vs. digital outputs:

DAC – AD558JNZ			**ATmega128RFA1**		
Logic low	Logic high	Input current	Voltage low	Voltage high	Output current
V < 0,8 V	V > 2,0 V	<100 uA	V < 0,1 V	3,3 < V <3,9	< 2 mA

The relative accuracy of this DAC is +/- ½ of LSB, when we use 0 – 2,56 V range this will be: $\left(\frac{1}{256}\right) \cdot 2{,}56 = 0{,}01\ V \cdot 0{,}5 = 0{,}005\ V$

OPERATIONAL AMPLIFIER – CA3130EZ

The operational amplifier will be used in two configurations as a closed loop amplifier and a voltage follower. The operational amplifier will be used with the end position sensor, weft sensor and together with the DAC.

The datasheet for the CA3130 series can be found here[13].

Voltage amplifier:

In order to not compromise the DAC performance and increase the time, the wanted output voltage which will settle the operational amplifier has to be able to change the output as fast as the DAC. This will depend on the voltage follower's slew rate.

The voltage output range of the operational amplifier will be 0- 5 V. When using the CA3130 as a close-loop amplifier the slew rate is 10 V/µs, the operational amplifier will therefore reach it maximum output in 0,5 µs.

If the DAC has a maximum output voltage of 2,56 V the operational amplifier has the gain:

$5\ V \frac{1}{2.56} = 1{,}9531$

To ensure we do not exceed 5 V the gain will be set to 1.9. The gain of the operational amplifier is determined by:

$$1.8 = 1 + \left(\frac{R12}{R13}\right) \rightarrow \frac{1\ M\Omega}{0,8} \approx 1,2\ \mathrm{M}\Omega$$

Figure 14 illustrates this circuit, the 1,1 MΩ will be replaced with a 1,2 MΩ.

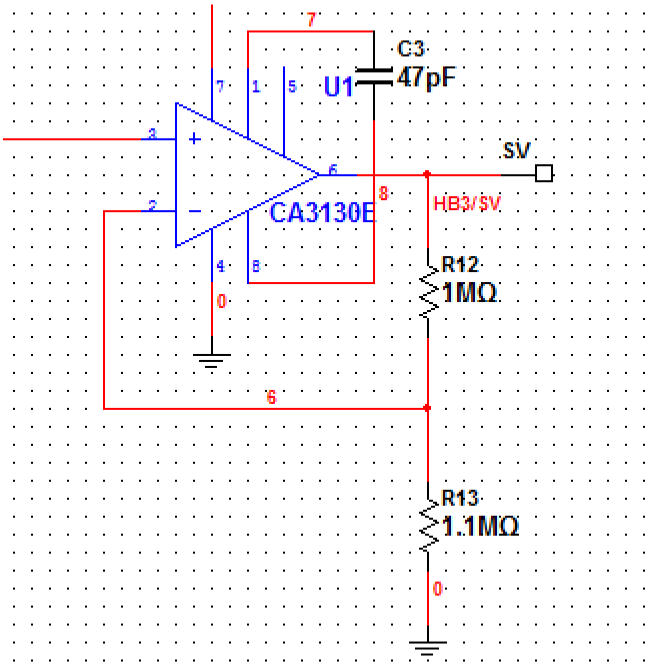

Figure 14: Example of voltage gainer, CA3130EZ

VOLTAGE REGULATOR – L7812ACV

The voltage regulator will also power the ATmega128RFA1, STK600 and the weft sensor circuit.

The datasheet for voltage regulator, L7812ACV[14].

The one we ordered has the package TO-220.

The main task of the regulator circuit is to regulate the input voltage of 24 V to an output voltage of 12 V.

The voltage regulator is rated with a maximum output current of 1 Ampere. But on our breadboard test, no heat sink is planned to be mounted.

Calculation variables for heat dissipation:

R_{thJC} = Thermal resistance junction-case, for L7812ACV this is 3^0C/W.
R_{thJA} = Thermal Resistance junction-ambient, for L7812ACV this is 50^0C/W.

So if we are using 1 ampere as output, we need a heat sink that has a thermal resistance of 53^0C/W.

Maximum amount of power, without heat sink:

T_{OP}= Maximum junction temperature in ºC, for L7812ACV this is 150 ^{0}C.

When we define the maximum amount of power, two things have not been considered:

- The voltage regulator is mounted on a breadboard limiting R_{thJA} because the breadboard is isolating the voltage regulator.
- Very little air has been replaced around the voltage regulator, so an ambient temperature is assumed to be 40 ^{0}C. This because the regulator heats up the around it, and with no air being replaced, the surrounding air is higher than the room temperature.

  Equation for max power that can be dissipated:

$$150\ ℃ = \left(53\ \frac{℃}{W} * x\right) + 40\ ℃ \approx 2\ Watt$$

$$Itotal = \frac{Power}{(Vin - Vout)} = \frac{2}{(24 - 12)} = 0{,}166\ A = 166\ mA$$

Maximum amount of power if Vin is reduced:

In order to reduce the power dissipation, an effect resistor can be mounted in series with Vin.

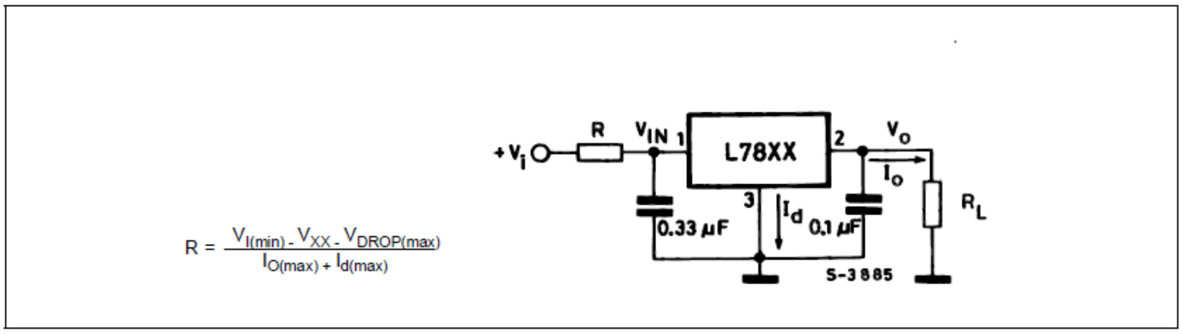

Figure 15: Reducing Power Dissipation with Dropping Resistor[14]

If we reduce the input voltage to 15 V, the maximum amount of current without the heat sink will be:

$$Itotal = \frac{Power}{(Vin - Vout)} = \frac{2}{(16 - 12)} = 0{,}5\ A = 500\ mA$$

The effect transistor shouldn't handle more than 5 Watt. It has to handle:

$$P_{Resistance} = V_{resistance} \cdot I_{total} = (24 - 16) \cdot\ 0{,}5\ A = 4\ W$$

Calculating the resistance:

$$R = \frac{V_{IN} -\ Vxx - V_{drop}}{Io - Id} = \frac{24 - 16 - 0{,}3}{0{,}5} \approx 15{,}4\ Ohm$$

BACKUP DESIGN

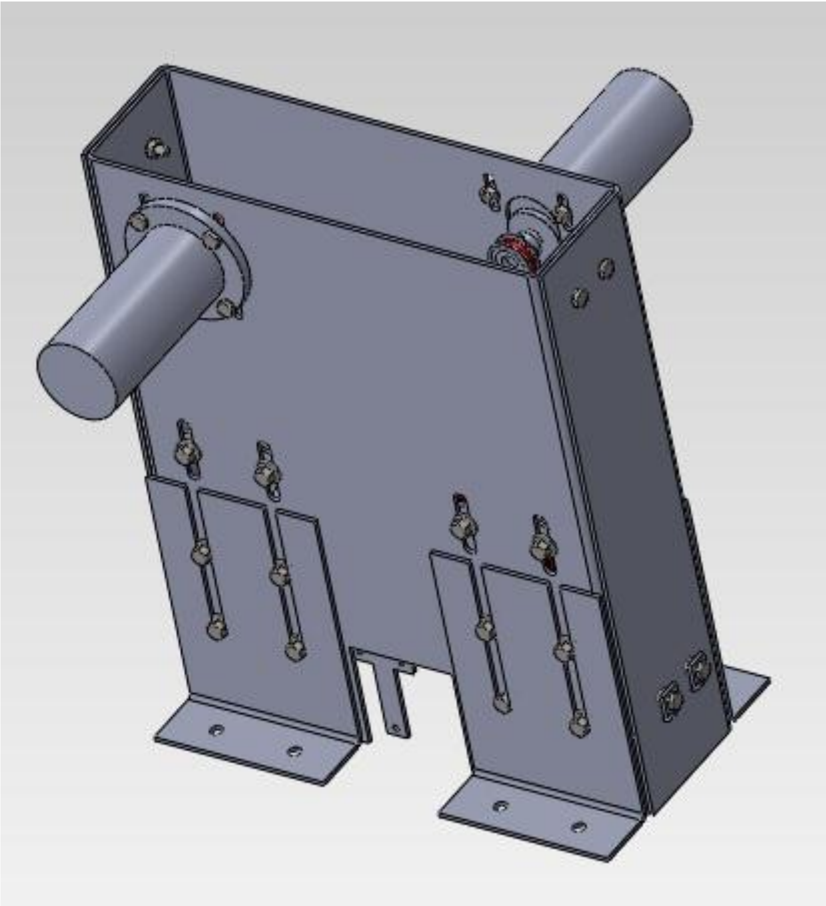

Figure 16: Backup thread selection

The backup design illustrated in Figure 16 will contain 2 arms and 2 motors. The system will be able to handle two threads. The principle for the system is the same as moving overhead arm. The reason we went for the backup design is mainly due to expensive parts in the original design. The price for timing belts and pulley wheels for one module on the original design is 8500NOK. One module on the original design is able to handle four arms, for a total of eight arms the price for only timing belts and pulley wheels will be 17 000NOK. This is not included motors (four motors per module). The high cost of the pulley wheels is due to machining after costumers specification. In the backup design the timing belts and pulley wheels are standard components. We were not able to use standard pulley wheels in the original design because of the small design. The disadvantages with the backup is the size, this module will not fit the TC-2.

PULLEY WHEELS AND AXLE

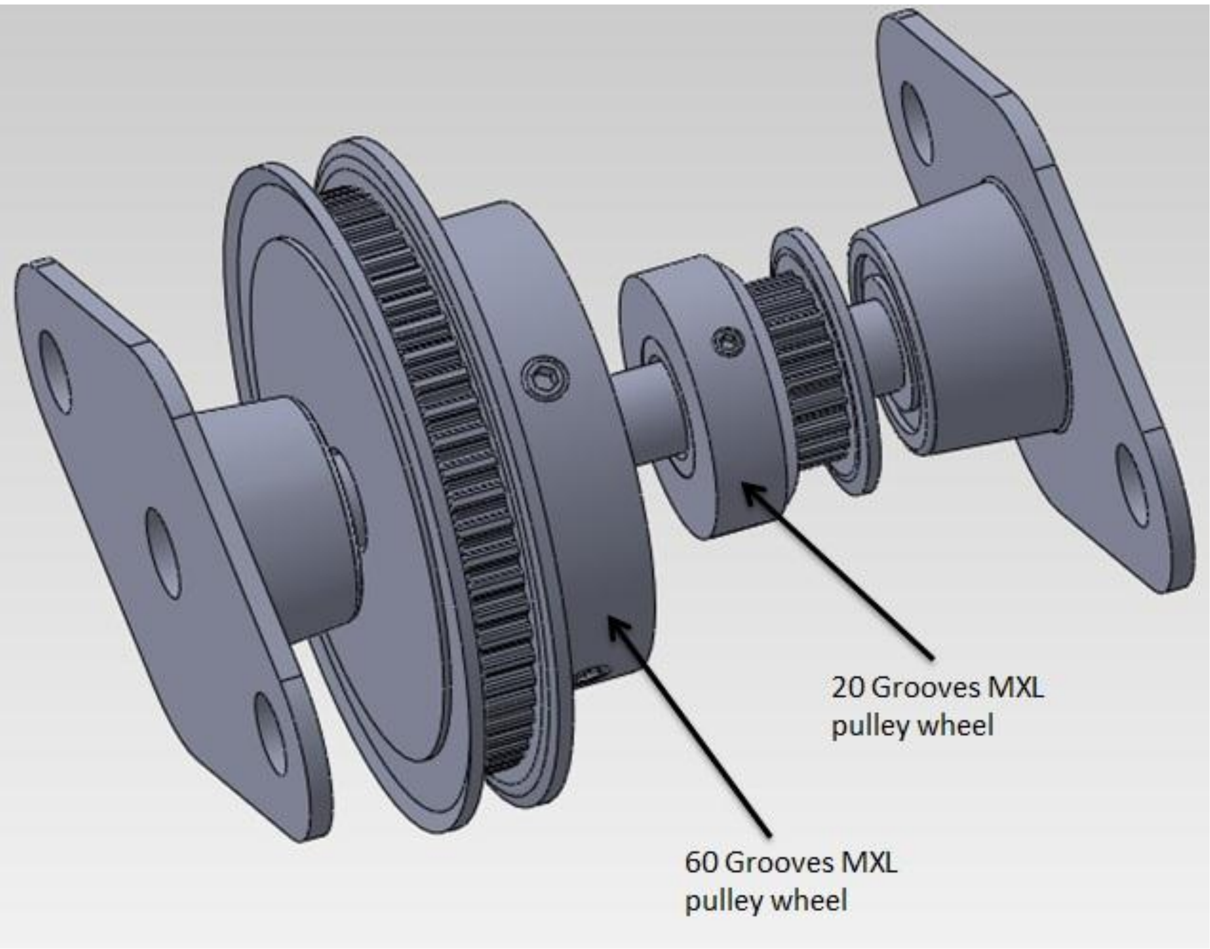

Figure 17 Illustration of upper pulley wheels

The two pulley wheels are attached to the shaft with set screws on the hub. Datasheet for pulley wheels [15]. The pulley wheels are the MXL series, the pitch are 2,03mm and fits for MXL timing belts with width up to 3mm. The shaft is inserted into the two flanged needle bearings through a press fit. Pulley wheel with 60 grooves will be driven by the Faulhaber motor. The upper pulley wheels are simply to gear the motor. We were given the Faulhaber for testing. In the original design we must choose much smaller motors. This result in much less torque and therefore we need gearing to achieve the torque needed. We choose to keep the upper pulley wheel only for testing of the system and concept testing of the module, even though the torque of the Faulhaber is large enough to drive the system without gearing.

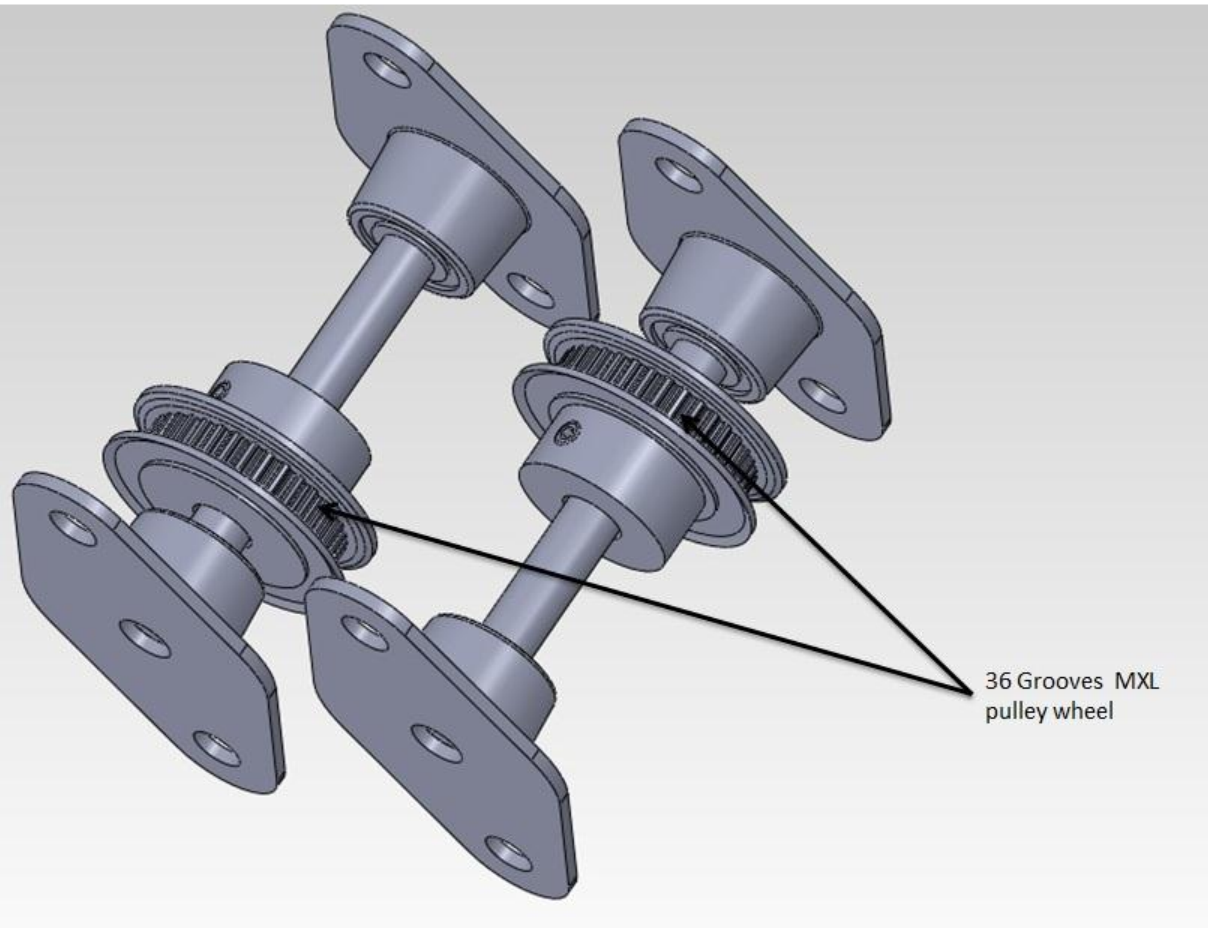

Figure 18 Lower pulley wheels

The lower pulley wheels are illustrated in Figure 18. It is the same concept as the upper pulley wheels except the lower pulley wheels only consists of one pulley wheel. The lower pulley wheels are mounted on individual shafts for individual rotation.

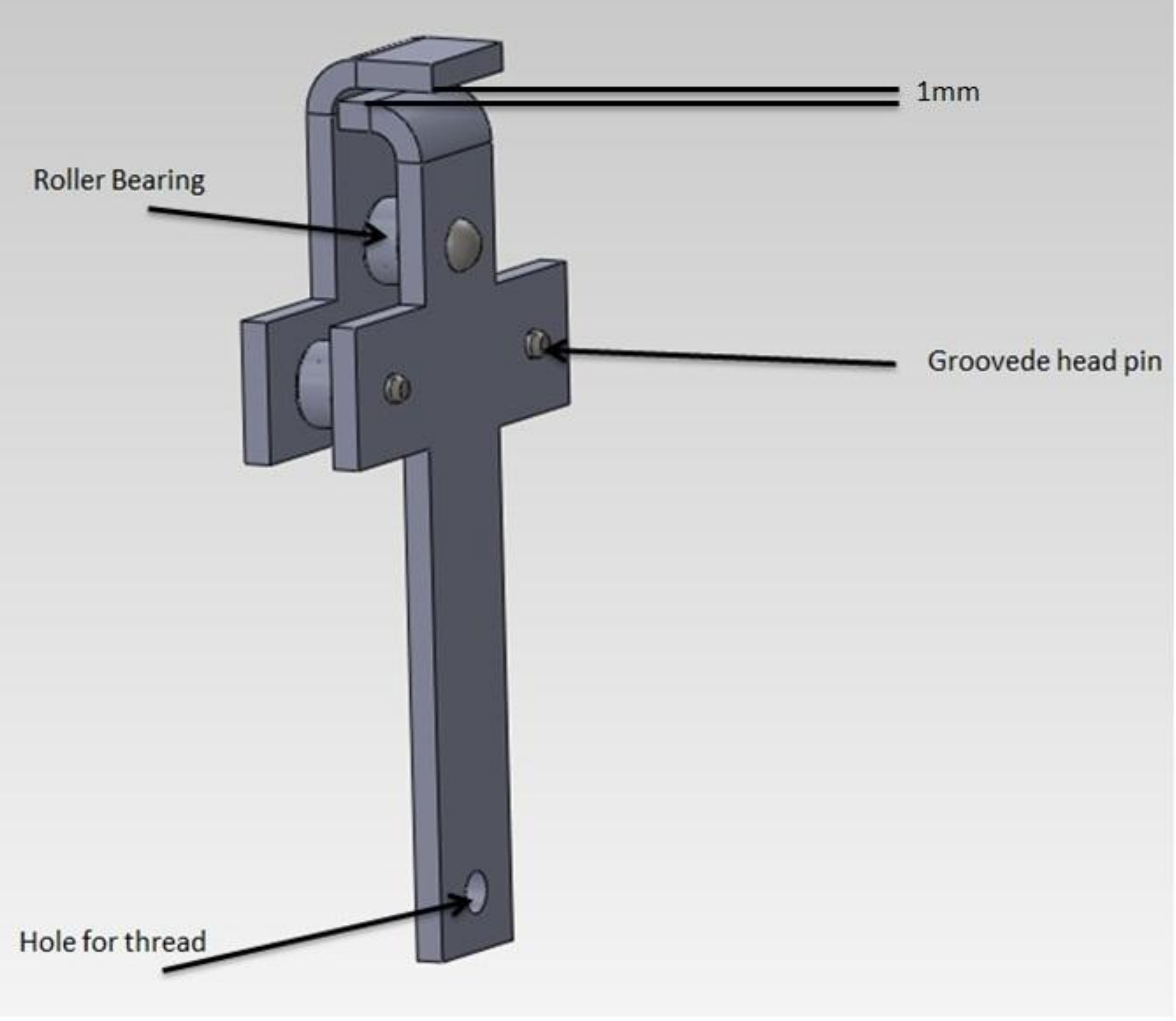

Figure 19: Arm

The only difference from the original design is the top. For fastening of the timing belt, there is a 1mm gap on the top between the sheet metal plates as illustrated in Figure 19. The arm consists of two steel plates which are attached with round head groove pins. On the pins its attached roller bearings, that is put in place for less friction for the arm. The roller bearings will glide along the guide rail. The plates for the arm and guide rail will be machine pressed and buckled. The hole for thread has a diameter of 3mm. Data sheet[16] for roller bearings on Figure 19.

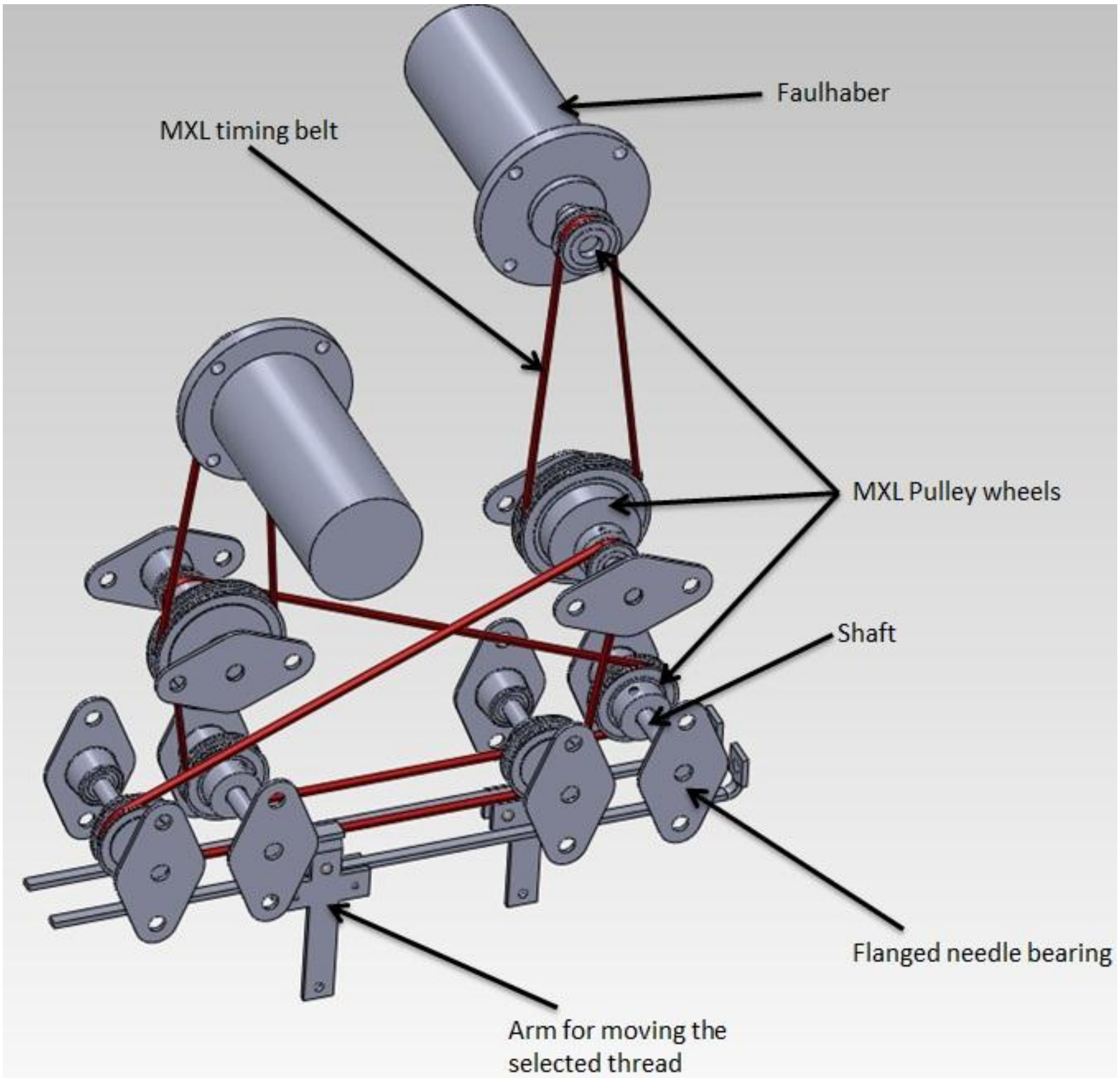

Figure 20: Backup selection system

Figure 20 illustrates the backup design. The principle is the same as the original design. The main difference is the size of both the module and the size. The number of total arms is also reduced from four till two. The original design used the TN-10 series of timing belts and pulley wheels. The backup uses the MXL series. The reason the MXL is chosen in this solution is size and price. For datasheet on MXL timing belt [17]. The breaking strength on the timing belts are 336N and 546N.

The rotational movement of the motor will result in linear movement of the thread arms. The upper pulley wheels are mounted on the same shaft, which results in that both pulley wheels rotates simultaneously. The shaft is inserted to two press bearings, one on each side. This requires a tolerance finish on the shaft. Since the lower pulley wheels requires individual rotation, and we attach the pulley wheels with a set screw. This does not allows us to have pulley wheels on the same shaft as on the original design, where the pulley wheels where inserted with ball bearings that resulted in individual rotation. On the backup design we have one shaft per pulley wheel. This results in more parts and a larger module. The pros are that we do not use machine parts. The machine parts are more expensive and the order time is longer.

The backup design illustrated on Figure 21 now consists of two sheet metal plates. The thickness is 2mm, this is a great reduction from the original design which consists of only one sheet metal plate and had a thickness of 1mm. The thickness is increased because the module is larger and therefore we included the extra support with increasing the thickness of the plate. The design of the backup solution made it difficult to only use one sheet metal plate. The garage is where the gripper enters to pick up the selected thread. There are adjustable tracks for the motors and upper pulley wheels - this is for tightening of the timing belts. The brackets is to adjust the height of the “garage”, this is only because we are uncertain about the height the gripper will enter the “garage”.

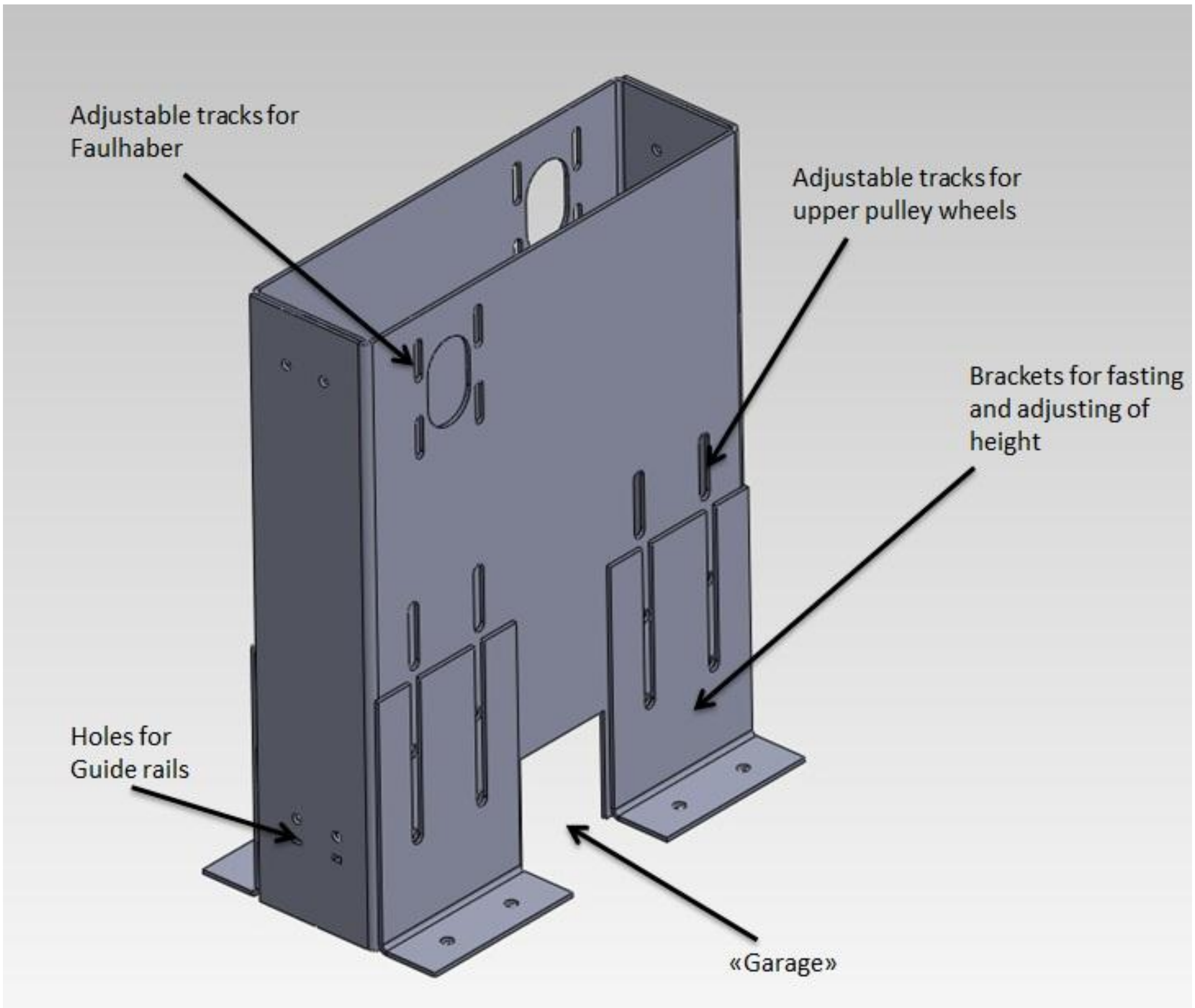

Figure 21: Thread selection casing

ARM CONTROLL

The arms will be controlled by Faulhaber MCBL2805.

FAULHABER 2805

The Faulhaber MCBL 2805 is a motion controller. It's used with a Faulhaber 3564k 024B K1155 BLDC motor. The controller can be programmed via serial (null modem/RS-232 cable) and thereafter controlled by the Ain(analog speed control) or TxD/RxD (serial) inputs. It also has a programmable "fault" output, which can also be programmed as an input for other uses.

SETTING UP THE MCBL 2805

The MCBL are programmed by serial. The layout of the circuit is as follows:

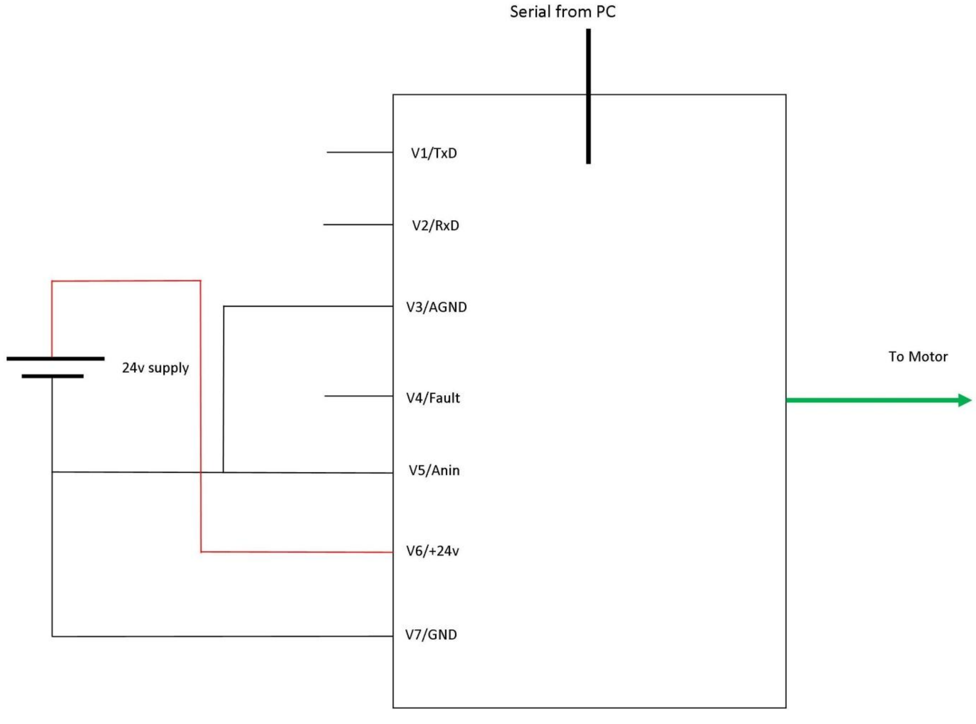

Figure 22: Faulhaber programming circuit

After the setup above, the program "Motion manager" from Faulhaber, was run on the connected computer. Motion manager is a program that allows for real-time programming and the gathering of information like RPM (measured and commanded) and position of the motor.

The configuration of the serial is important. The communication consists of 8 bits and 1 stop bit, without parity and flow control. The baud rate is 9600 by default and will be used since its more than fast enough for this task.

The serial communication is done with ASCII. The Motion manager automatically sets up the selected motor and filters after the correct motor has been selected in “Motion manager”. This can also be done manually with the following lines, by HyperTerminal or other serial communications programs:

- MOTTYP8 (Sets the motor to be controlled as 3564k 024B k1155, table page 13 in datasheet).
- POR8 (sets the proportional term, command from page 19, and value from table page 13).
- I20 (sets the integral term, command from page 19 and value from table page 13).

To achieve the most efficient controller, the motor and controller is tested for jumps in speed several times with an increase in the proportional term for each time until instability is achieved, then lowered to stability. Then this is repeated, but instead of changing the proportional term, the change is done in the integral term.

Then the currents will be controlled. All values are fetched from the table on page 13 in the datasheet.

- LP8000 (limits the motor peak at 8000mA=8A).
- LCC2800 (sets the continuously current to 2800mA=2,8A).

Since the MCBL 2805 will be set up as a position controller that receives a “go” from a master, the controller needs these lines to be readjusted to position control:

- SOR0 (switches to serial communication in speed control mode).
- LR0 (Sets relative position to 0).
- M (activates the position control).

These variables are automatically set by Motion Manager when the right motor is selected within the program.

After the initial set up, the controller needs to be set up according to the needs of the system, where the key factors are:

- Acceleration.
- Position.
- Time.

As the MCBL 2805 is a PI motion controller, position does not look like a problem at the time. To become familiar with the MCBL 2805, we decided to make a little test program (note: this was just a small "get to know the drive" program). The program was as follows:

HO0 (sets the current position as home position)

LA100000 (Sets an absolute position)

AC50 (Sets the acceleration of 50 revs/s^2)

SP3000 (sets max speed at 3000 rpm)

A1 (jump-in point)

LR100000 (adds 100000 to the already set absolute position)

M

DELAY500 (stops the sequence for 5 seconds)

TIMEOUT500(waits 5 seconds for notified command to be sent)

LR-100000 (subtracts 100000 for the absolute position)

M

DELAY500

TIMEOUT500

JMP1 (jumps to A1)

As regards to this code, some of the lines are unnecessary, like the DELAY500. The delay did not seem to work as hoped, and therefore timeout was implemented to halt the running of the program, even if no notifications were to send. We have two simple notification commands:

- NPx (notifies when the motor has come to position x, with a "p" over TxD)
- NVx (notifies when the motor has a velocity of x, with a "v" over TxD)

This is useful for later use - it can be used to notify the master microcontroller that the motor has reached its destination. We will probably only use NPx for this project.

To explain the commands better:

- LAx is, as mentioned, the command that sets the position the motor should work towards. Each rotation is equal to 1000, giving a resolution of 1/1000 of a rotation.
- ACx is how fast the controller will let the motor accelerate. This is very useful for our system to avoid slip in the timing belts.
- SPx sets the max RPM for the motor.
- Ax is a jump-in point. It can have a total of 64 jump-in points (0-63).
- LRx adds to the LAx. It uses the same resolution as LAx.
- DELAYx stops the sequence for x/100 seconds.
- TIMEOUTx halts the sequence for x/100 seconds.
- JMPx loops to Ax.

To achieve the same starting position each time, a homing sequence is required. This sequence is programmed into the EEPROM on the Faulhaber.

- HA is home arming. On an edge, position will be set to 0.
- HL is hard limiting. On an edge, the motor will stop.
- HN is hard notify. On an edge, the controller will notify the master over serial.

This will then be saved as a homing sequence.

- CAHOSEQ saves the HA, NL and HN values.
- POHSEQ1 activates the homing sequence on power on.
- ENPROG enables the program.
- ANSW is asynchrony answering (1-true, 0-false).

- EEPSAVE saves the configuration into the EEPROM.

This will also be used with a command for setting the node address to be able to use more than one controller on the serial.

- NODEADRx, where x is the address for the controller.

Now the foundation for programming the Faulhaber is done.

MODULE 23: THREAD HOLDING SYSTEM

MECHANICAL SOLUTION

The thread holding system will be made out of sheet metal. Sheet metal parts is relatively cheap to manufacture, and is made by cutting or pressing out holes and cavities and later bending the edges to form the part. This can both be done by manual and automatic machines. The metal will be 2.5mm thick for the actual holding system, while the thread tray will be made of 1mm thick metal. Figure 23 shows these two parts.

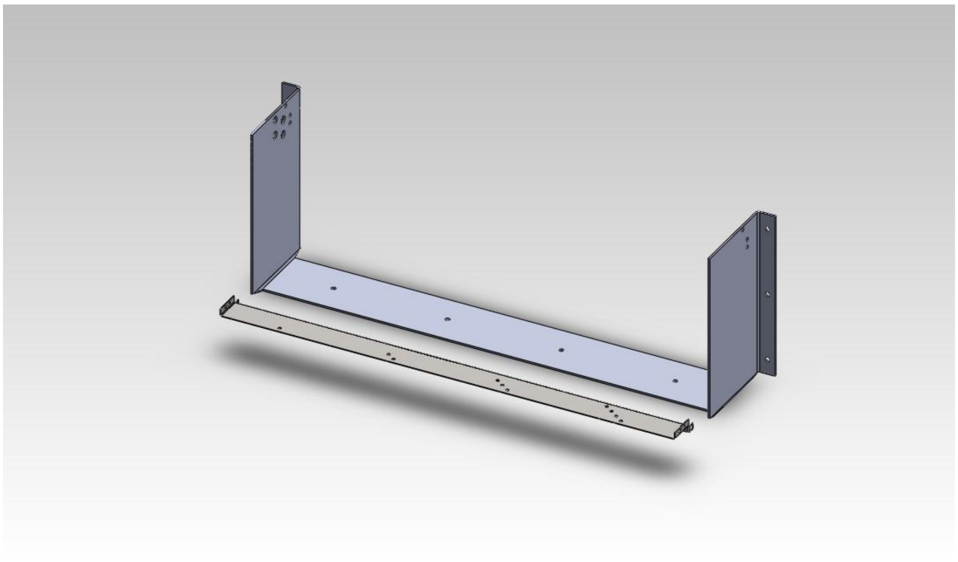

Figure 23: Thread holding system

Eltex of Sweden[18] has suggested us to use their G3w sensor, as illustrated in Figure 24.This sensor gives a stop signal 2 ms after the thread has stoped. The sensor is primarily made for rapier machines with 1200 meters of picks per minute, but we have tested it and there seems to be no problem for it to sense the slow yarn speed we will be using in our product. It has to be noted that the angle of the thread through the sensor hole is important. The angle should ideally be around 10-15° or more. If the weaver is using Carbon fiber, Eltex of Sweeden needs to add a protection layer on the sensor elements and on the circuit board. That's because loose fibers can resault in short-circuit. In this project we will assume that carbon fiber is not used.

Figure 24: G3w-yarn sensor

The sensor is operating on 24V DC ±25%. That means down to 18V DC and up to 30V DC. It will never consume more than 125mA. As for today, there is a 24 volt and a 12 volt power supply on the TC2, but only the 12 volt supply is available for us to use in our module. We may therefore need to construct or buy a DC-DC converter which will transform the 12V DC up to 24V DC. For the first prototype we will simply use an external 24V power supply to operate it.

The sensor can detect whether zero, one, two, or three and more threads are moving. Current logic signals are as following:

- 0 weft yarns moving: <0.1 mA
- 1 weft yarn moving: 2.73 mA ±8%
- 2 weft yarns moving: 5.46 mA ±8%
- 3 or more weft yarns moving: 8.19 mA ±8%

This can be used for different scenarios. When the microcontroller expects that the gripper has grabbed a thread, it can do a control on the yarn sensor to find out whether it actually is pulling the yarn. If it does, it should output around 2.73mA. If it doesn't, it might mean that there's no more yarn left on the spool, that it accidently did not grab the thread or that the thread is broken. In either way, the gripper will finish it's cycle in slow speed and then halt the system. This reduced speed will be an indication for the weaver that something went wrong and need maintenance. The weaver will now has to press the sw0-button on the STK600 to start a new cycle; but before the button is pressed, the spool has to be changed or the broken thread might need to be put back to its initial position. Also, it might be necessary for the weaver to do some changes in the pattern-software so that it repeats the last pick one more time. It might be possible to do this change automatically, but not without software changes in the TC2's motherboard.

If the gripper picks two or three yarns at the same time, we will use the comparator's interrupt functionality to halt the system as soon as this occurs. There are different reasons for why we want to use interrupt to halt the system immediately if the gripper pulls multiple threads, instead of continue the pick before the system halts:

- Less waste of threads.
- Avoid more current consumption than necessary.
- Avoid unexpected scenarios and damages on the system.
- Less calculation costs.

When the gripper unexpectedly pulls multiple threads, this will be indicated with that the gripper halts. The weaver will has to set the threads back to the initial position, and then press the sw0-button to move the gripper arm slowly back to its initial position, and then press the same button again to start a new cycle.

The gain/sensitivity setting is from 0-6.5V DC external, and the sensor is connected through a DB-9 male plug. We will be using 6V to trigger good sensitivity. To get 6V, we use the 12V power supply, with voltage division, with each resistor in the voltage divider having the value of 10kΩ. The Figure 25 shows how the weft sensor should be connected

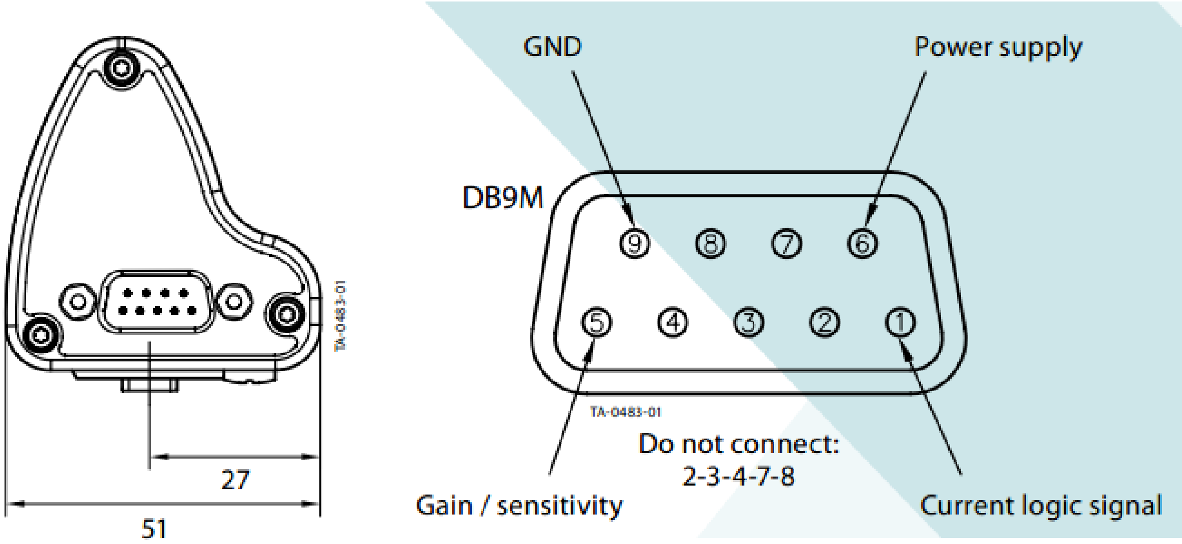

Figure 25: Connection to the sensor

As mentioned, the sensor is outputting different currents, not a voltage directly. The microcontroller has an analog comparator with a minimum input voltage of GND minus 0.5volts, and a maximum input voltage of VCC plus 0.5 volts. That means that we can compare every voltages between -0.5V and +3.9V (we are using VCC=3.4V). To be safe, we will newer exceed 3.4V. We will use a fixed shunt-resistor on the positive input to ensure that the analog comparator never exceeds this value.

The resistor value is easily calculated with ohms law.

$$R = \frac{U}{I} = \frac{3.4V}{8.19mA + 8\%} = 384{,}4\Omega$$

A 330 ohm resistor has a tolerance of 5%, which can be no more than 346,5ohm. In worst case scenario we could get a voltage of 3,06Vwhich is inside the 3,4V-limit for the Analog Comparator.

We will also use a protection resistor on the voltage analog inputs on the comparator, to ensure that the current through the two diodes integrated on the inputs, will not be too high. Figure 26[19] shows how this security circuit looks like. This circuit (except for the resistor) is built into all the I/O pins on the AVR. If the input voltage exceeds VCC plus the conduction voltage of the diode (around 0.5V), the upper diode will conduct, and the input voltage will never be higher than VCC+0,5V. The same goes for a too low voltage.

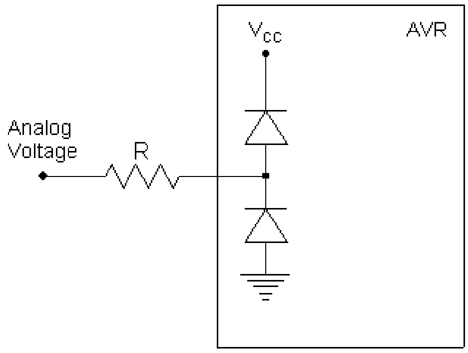

Figure 26: Security circuit

The value of the resistor has to be calculated so the current through the diodes never exceeds 1mA. U is set to 3,4V because we have calculated that the input of the pin will never exceed 3,4V.

$$R = \frac{U}{I} = \frac{3{,}4V}{1mA} = 3400\Omega$$

In reality it would never occur that the diode will get close to 1mA as long as we keep a voltage below VCC and above 0V as we do in this scenario. The protection resistor is more important if you risk getting for example 24V on the input. In that case, too much current would pass through the diode if the protection resistor wasn't in place. It could therefore be discussed how necessary it is to have this protection resistor on the PCB output for this task.

MODULE 30: CONTROLLER UNIT

INTRODUCTION

In this project we will be using a STK600 developer kit, with an ATmega128RFA1 mounted on it. The 128RFA1-card has a radio transceiver that will be used to communicate with the motherboard for the TC2 without wires.

ATMEGA128RFA1

The ATmega128RFA1 is the microcontroller we are programming on. It provides different functionalities like PWM, analog comparator, ADC, interrupts, wifi-communication, and more. All the pins can be configured as both input and output, and some of the pins have special functionalities. The microcontroller does not provide any DAC, so in this project we have used an external DAC for controlling the motor for the gripper arm.

Figure 27 and Figure 28 on the next page illustrates the ATmega128RFA1 CMOS 8-bit microcontroller. These ports are mapped on the next pages, with information from the datasheet[1].

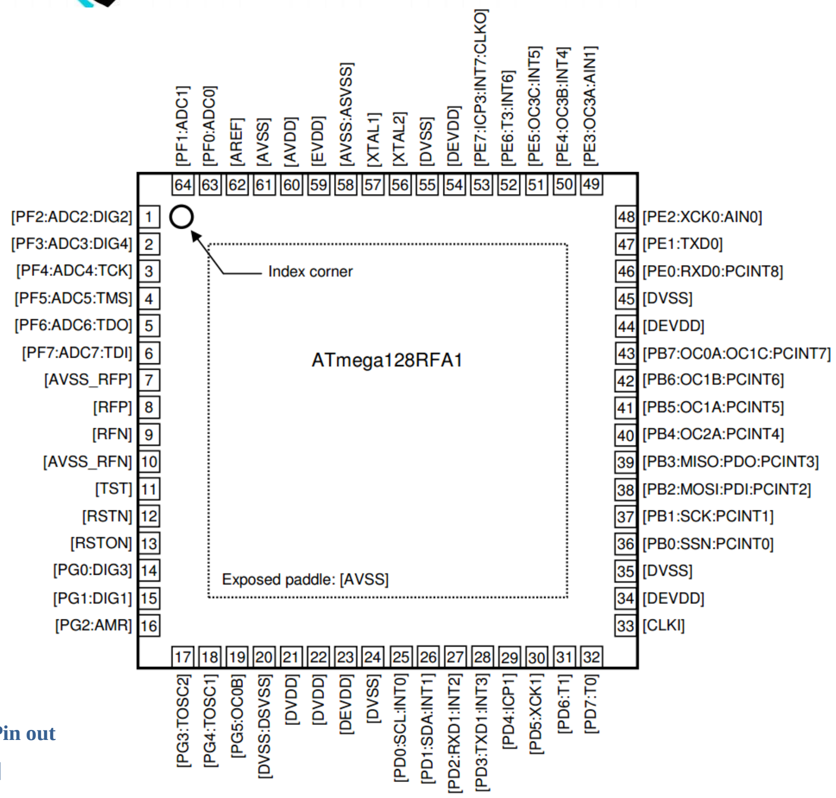

Figure 28: Pin out 128RFA1[1]

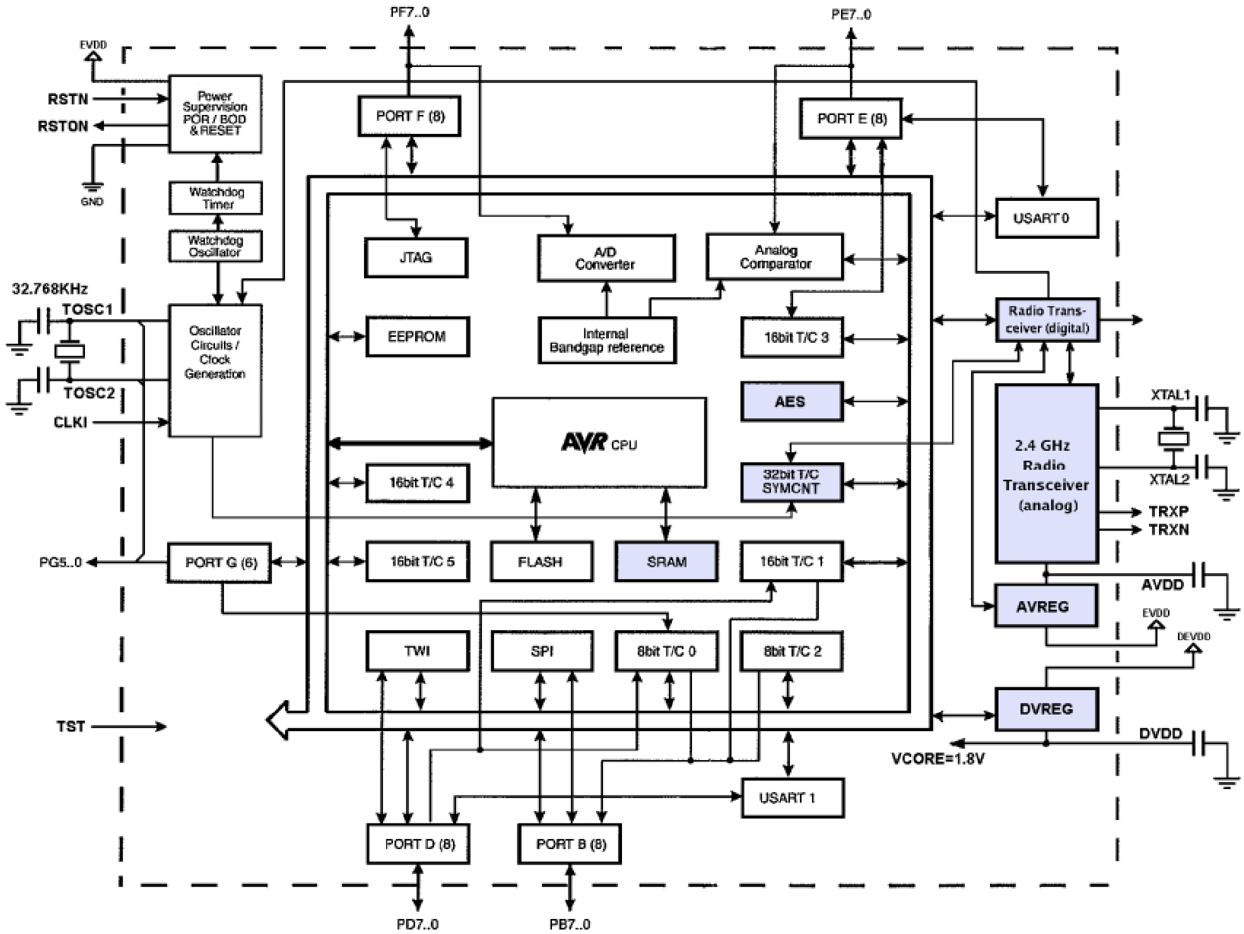

Figure 27: Block diagram[1]

PIN DESCRIPTION

Number	Name	Description
59	EVDD	External analog supply voltage.
34	DEVDD	External digital supply voltage.
60	AVDD	Regulated analog supply voltage (internally generated).
21	DVDD	Regulated digital supply voltage (internally generated).
24	DVSS	Digital ground.
61	AVSS	Analog ground
36-43	Port B (PB7...PB0)	8-bit bi-directional I/O port. It has internal pull-up resistors (selected for each bit). The output buffers have symmetrical drive characteristics with both high sink and source capability. As input, the pins that are externally pulled low, will source current if the pull-up resistor are activated. The pins are tri-stated when a reset condition becomes active, even if the clock is not running. Port B also provides functions of various special features of the ATmega128RFA1.
25-32	Port D (PD7...PD0)	8-bit bi-directional I/O port. It has internal pull-up resistors (selected for each bit). The output buffers have symmetrical drive characteristics with both high sink and source capability. As input, the pins that are externally pulled low, will source current if the pull-up resistor are activated. The pins are tri-stated when a reset condition becomes active, even if the clock is not running. Port D also provides functions of various special features of the ATmega128RFA1.
46-53	Port E (PE7...PE0)	8-bit bi-directional I/O port. It has internal pull-up resistors (selected for each bit). The output buffers have symmetrical drive characteristics with both high sink and source capability. As input, the pins that are externally pulled low, will source current if the pull-up resistor are activated. The pins are tri-stated when a reset condition becomes active, even if the clock is not running. Port E also provides functions of various special features of the ATmega128RFA1.
63-64 1-6	Port F (PF7...PF0)	8-bit bi-directional I/O port. It has internal pull-up resistors (selected for each bit). The output buffers have symmetrical drive characteristics with both high sink and source capability. As input, the pins that are externally pulled low, will source current if the pull-up resistor are activated. The pins are tri-stated when a reset condition becomes active, even if the clock is not running. Port F also provides functions of various special features of the ATmega128RFA1.

14-19	Port G (PG5...PG0)	8-bit bi-directional I/O port. It has internal pull-up resistors (selected for each bit). The output buffers have symmetrical drive characteristics with both high sink and source capability. **NB!** The driver strength on PG3 and PG4 is reduced compared to the other port pins. The output voltage drop ($V_{OH,}$ V_{OL}) is higherwhile the leakage current is smaller. As inputs, the pins that are externally pulled low, will source current if the pull-up resistor are activated. The pins are tri-stated when a reset condition becomes active, even if the clock is not running. Port F also provides functions of various special features of the ATmega128RFA1.
7	AVSS_RFP	AVSS_RFP is a dedicated ground pin for the bi-directional, differential RF I/O port.
10	AVSS_RFN	AVSS_RFN is a dedicated ground pin for the bi-directional, differential RF I/O port.
8	RFP	RFP is the positive terminal for the bi-directional, differential RF I/O port.
9	RFN	RFN is the negative terminal for the bi-directional, differential RF I/O port.
12	RSTN	Reset input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running. Shorter pulses are not guaranteed to generate a reset.
13	RSTON	Reset output. A low level on this pin indicates a reset initiated by the internal reset sources or the pin RSTN.
57	XTAL1	Input to the inverting 16MHz crystal oscillator amplifier. In general a crystal between XTAL1 and XTAL2 provides the 16MHz reference clock of the radio transceiver.
56	XTAL2	Output of the inverting 16MHz crystal oscillator amplifier.
62	AREF	Reference voltage output of the A/D Converter. In general this pin is left open.
11	TST	Programming and test mode enable pin. If pin TST is not used, pull it to low.
33	CLKI	Input to the clock system. If selected, it provides the operating clock of the microcontroller.

Table 1: Pin descriptions, from datasheet[1]

Even if a pin is not used, it is recommended that we define a level for these pins [1]. This is to reduce current consumption. This can be done easily by enable the internal pull-up resistor. Note that the pull-up will be disabled during reset, so if low power consumption is important during the reset, one should use an external pull-up or pull-down resistor instead. You should not connect the unused pins directly to DEVDD or DVSS because this may cause a big current consumption if the pin accidentally gets configured as an output.
The output pins are not floating pins, and does not need to be connected to an appropriate source.

Port A and Port C were previously (on the ATmega1281/2561) in use for "External Memory interface". This external memory was removed by two reasons:

1. The internal data memory (SRAM) is large, so it does not require any external memory.
2. With only SRAM in use, the system radiation (EMC) is very small, which is a great benefit for the very high sensitivity antenna input.

The Port A and Port C are therefore not available for use on the ATmega128RFA1

First three different C Code Examples (the first one from the datasheet [1]) of how to set pin 0 and 1 on port B as output high, pin 2 and 3 as output low, and define the port pins from 4 to 7 as input with pull-ups assigned to port pins 6 and 7. The first example uses the name of the pins, the next two examples uses binary and hexadecimal numbers to define the value of the pins.

```
unsigned char i;

/* Define pull-ups and set outputs high */
/* Define directions for port pins */
PORTB = (1<<PB7)|(1<<PB6)|(1<<PB1)|(1<<PB0);
DDRB = (1<<DDB3)|(1<<DDB2)|(1<<DDB1)|(1<<DDB0);
/* Insert nop for synchronization*/
__no_operation();
/* Read port pins */
i = PINB;
```

```
unsigned char i;

/* Define pull-ups and set outputs high */
/* Define directions for port pins */
PORTB = 0b11000011;
DDRB = 0b00001111;
/* Insert nop for synchronization*/
__no_operation();
/* Read port pins */
i = PINB;
```

```
unsigned char i;

/* Define pull-ups and set outputs high */
/* Define directions for port pins */
PORTB = 0xC3;
DDRB = 0x0F;
/* Insert nop for synchronization*/
__no_operation();
/* Read port pins */
i = PINB;
```

PORTB defines the use of Port B, and the PBn defines which number that will be used. The DDxn bit in the DDRx (Data Direction Register) defines the direction of the data. 0=input and 1 = output. "x" means the port letter (for example B) and "n" means the pin number on the port.

If a PORTxn pin is set high **and** as input, the internal pull-up resistor is activated. By changing one of these parameters, the pull-up resistor will be switched off. To disable the pull-up resistors on all the pins on all the ports, you can also set the "Pull-up Disable" (PUD) bit in MCUCR.

If a PORTxn pin is set high **and** as output, the port pin will go high. The opposite goes if the PORTxn is set low **and** as output. PINB (Pin In) is a read only-pin. If PINxn is set to logic one, the PORTxn value will toggle. If it was high, it will go low and vice versa. This is independent of whether the DDxn-bit is set high or low. PINxn is mostly used for reading pin values on outputs.

All this are summarized in Table 2.

DDxn	**PORTxn**	**PUD (In MCUCR)**	**I/O**	**Pull-up**	**Comment**
0	0	X	Input	No	Tri-state (Hi-Z)
0	1	0	Input	Yes	Pxn will source current if ext. pulled low.
0	1	1	Input	No	Tri-state (Hi-Z)
1	0	X	Output	No	Output Low (Sink)
1	1	X	Output	No	Output High (Source)

Table 2: Configuration of I/O ports[1]

As mentioned, most of the pins also have different alternate functions. Some of these functions, for instance the analog comparator (PE2 and PE3) and USART transmit/receive (PD2 and PD3), has been useful in our project. The following is a summary of the different inputs/outputs from 128RFA1. The tables below are fetched from the 128RFA1 datasheet.

Port B:

- **PB7:** OC0A/OC1C/PCINT7
- **PB6**: OC1B/PCINT6
- **PB5:** OC1A/PCINT5
- **PB4:** OC2A/PCINT4
- **PB3:** MISO/PDO/PCINT3
- **PB2:** MOSI/PDI/PCINT2
- **PB1:** SCK/PCINT1
- **PB0:** SS/PCINT0

OCnx = Output Compare and PWM Output _x_ for Timer/Counter _n_
PCINTn = Pin Change Interrupt _n_
MISO = SPI Bus Master Input/Slave Output
MOSI = SPI Bus Master Output/Slave Input
PDO = Programming Data Output
SCK = SPI Bus Serial Clock
SS = SPI Slave Select input

(For more details, see datasheet 14.3.1 - Alternate Functions of Port B from page 194).

Port D:

- **PD7:** T0
- **PD6:** T1
- **PD5:** XCK1
- **PD4:** ICP1
- **PD3:** INT3/TXD1
- **PD2:** INT2/RXD1
- **PD1:** INT1/SDA
- **PD0:** INT0/SCL

Tn = Timer/counter _n_ Clock Input
XCKn = USART_n_ External Clock Input/Output
ICPn = Timer/Counter_n_Input Capture Trigger
INTn = External Interrupt_n_ input
TXDn = USART_n_ Transmit Pin
RXDn = USART1 Receive Pin
SDA = TWI Serial Data
SCL = TWI Serial Clock

(For more details, see datasheet 14.3.2 - Alternate Functions of Port D from page 197).

Port E:

- **PE7:** INT7/ICP3/CLK0
- **PE6**: INT6/T3
- **PE5:** INT5/OC3C
- **PE4:** INT4/OC3B
- **PE3:** AIN1/OC3A
- **PE2:** AIN0/XCK0
- **PE1:** TXD0
- **PE0:** RXD0/PCINT8

INTn = External Interupt_n_ Input

ICPn = Timer/Counter_n_ Input Capture Trigger

CLKn = Divided System Clock

T3 = Timer/Counter_n_ Clock Input

OC3x = Output Compare and PWM Output _x_ for Timer/Counter_n_

AIN1 = Analog Comparator Negative Input

AIN0 = Analog Comparator Positive Input

XCKn = USART_n_ External Clock Input/Output

TXDn = USART_n_ Transmit Pin

RXDn = Usart_n_ Receive Pin

PCINT8 = Pin Change Interrupt8

(For more details, see datasheet 14.3.3 - Alternate Functions of Port E from page 199).

Port F:

- **PF7:** ADC7/TDI
- **PF6**: ADC6/TDO
- **PF5:** ADC5/TMS
- **PF4:** ADC4/TCK
- **PF3:** ADC3/DIG4
- **PF2:** ADC2/DIG2
- **PF1:** ADC1
- **PF0:** ADC0

ADCn = ADC input channel _n_

TDI = JTAG Test Data Input

TDO = JTAG Test Data Output

TMS = JTAG Test Mode Select

TCK = JTAG Test Clock

DIG4 = Radio Transceiver RX/TX Indicator Output

DIG2 = Radio Transceiver Antenna Diversity Control Output

(For more details, see datasheet 14.3.4 - Alternate Functions of Port F from page 201).

Port G:

- **PG5:** OC0B
- **PG4**: TOSC1
- **PG3:** TOSC2
- **PG2:** AMR
- **PG1:** DIG1
- **PG0:** DIG3

OCnx = Output Compare and PWM Output _x_ for Timer/Counter_n)
TOSCx = RTC Oscillator Timer/Counter2
AMR = Automated meter reading - Counter Input for Timer/Counter2)
DIG1 = Radio Transceiver Antenna Diversity Control Output
DIG3 = Radio Transceiver RX/TX Indicator Output

(For more details, see datasheet 14.3.5 - Alternate Functions of Port G from page 203).

INTERUPTS

Interrupts will be important together with the different sensors in our module to get a fast reaction when something needs to happen. For example will the weft sensor need to halt the whole system when the gripper accidently pulls two threads. We can then use the program address $0038 Analog Comparator vector to get this interrupt.

The different interrupts is “assigned” to different pins. Which interrupt contains which pin was mention earlier in "Alternate port functions".

Port E has built-in comparator functionality. The following picture, Figure 29, shows a block diagram for the comparator:

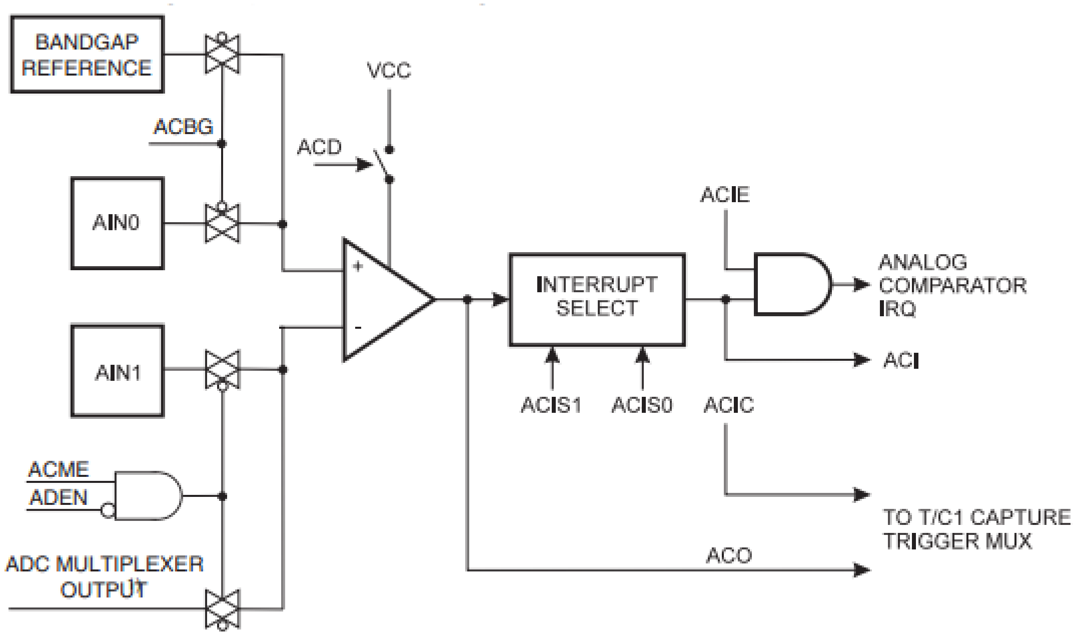

Figure 29: Block circuit Analog Comparator[1]

Both AIN0 and AIN1 are normally enabled, so no configuration needed in the DDR register (direction) to enable the comparator input. The Analog Comparator Output (ACO) will be high when AIN0>AIN1. The 128RFA1 also has the ability to have multiple fixed inputs which can be used instead of AIN1. To do this, one has to use the ADC-inputs on Port F together with a multiplexer. When this is done, the different ADC-input voltages will be the fixed input on the negative input of the op-amp.

As mentioned under the Module 22 - Technical solutions, the voltage on AIN0 for 3 or more threads can be between 2,36V and 3,06V. For two threads we can get a voltage between 1,57V and 2,04V. For one thread we can have a voltage between 0,78V and 1,02V. For zero threads moving, we will have a voltage of about 0V.

We will use two fixed reference voltages on the inverting input of the analog comparator:

- ADC0 will be set to 1,3V. This will be used with interrupt, and be the first position for the analog comparator when the gripper grips the thread. If the Analog Comparator Interrupt (ACI) gets high, it means that the gripper has accidently gripped multiple threads, and we then want the system to halt immediately.
- AIN1 will be set to 0,5V. This will be used without interrupt, but instead one or more if-sentences that reads the value of ACO on the gripper's way backward. When ACO is 0, it means that there's no movement on the thread. This can be when the gripper is not supposed to grip a thread, or when it misses a thread, when the thread breaks, or when there's no more thread left on the spool. When this occurs, the gripper will go slowly back to its initial position. The weaver will have to do what's necessary with the broken thread, and then press the sw0-button to start a new cycle .
  When ACO is 1, it means that the system is operating as it is supposed to.
-

In summary, we will first ensure that it's not more than one thread on the gripper. If it is, the interrupt-flag will be set and the system will halt immediately. Next, we will find out whether the ACO is high or low when the multiplexer is switched to AIN1. It should usually be high, but if the weft sensor of any reason does not detect that the gripper grabbed a thread, the gripper will return to its initial position with reduced speed and the weaver will be warned.

As mentioned, we will be using 0,5V and 1,3V as reference voltages. We will use the 12V main power supply and voltage division to get these voltages. To get 0,5V, we use 10kΩ together with a 430Ω resistor. To get 1,3V, we use 10kΩ together with a 1300Ω resistor.

We identified current leakage on pin 2, 3 and 4 on Port E. Pin 2 and 3 are the AIN0 and AIN1 on the comparator. This affected the voltage on the pins, and we therefore had some trouble to get the analog comparator to work as it was supposed to. After some research, and support from teacher, external advisor, AVRfreaks.net and AVR support, we found that the problem was that since the 128RFA1 is an evaluation board, AVR have mounted some LEDs to indicate transmission and reception of RF frames. These LEDs are connected to VTG_INT in series with resistors, and then directly to PE2, PE3 and PE4.

AVR support suggested us to remove these resistors to fix our problems. We got permission from our employer to do this, and the result was positive. We now got the correct voltages on the pins on Port E, and can now use calculated voltages on the reference pins.

Figure 30 [20] illustrates the components that have caused the problems with the current leakage.

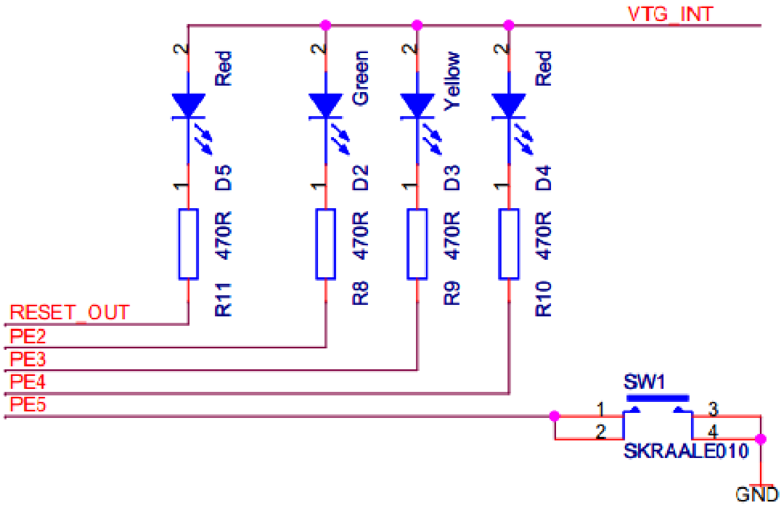

Figure 30: LEDs for RF indication

8 BIT TIMER/COUNTER0

The ATmega 128RFA1 is equipped with 8-bit and 16-hardware counter/timers. We have chosen the 8 bit counter for our application.

Figure 17-1. 8-bit Timer/Counter Block Diagram

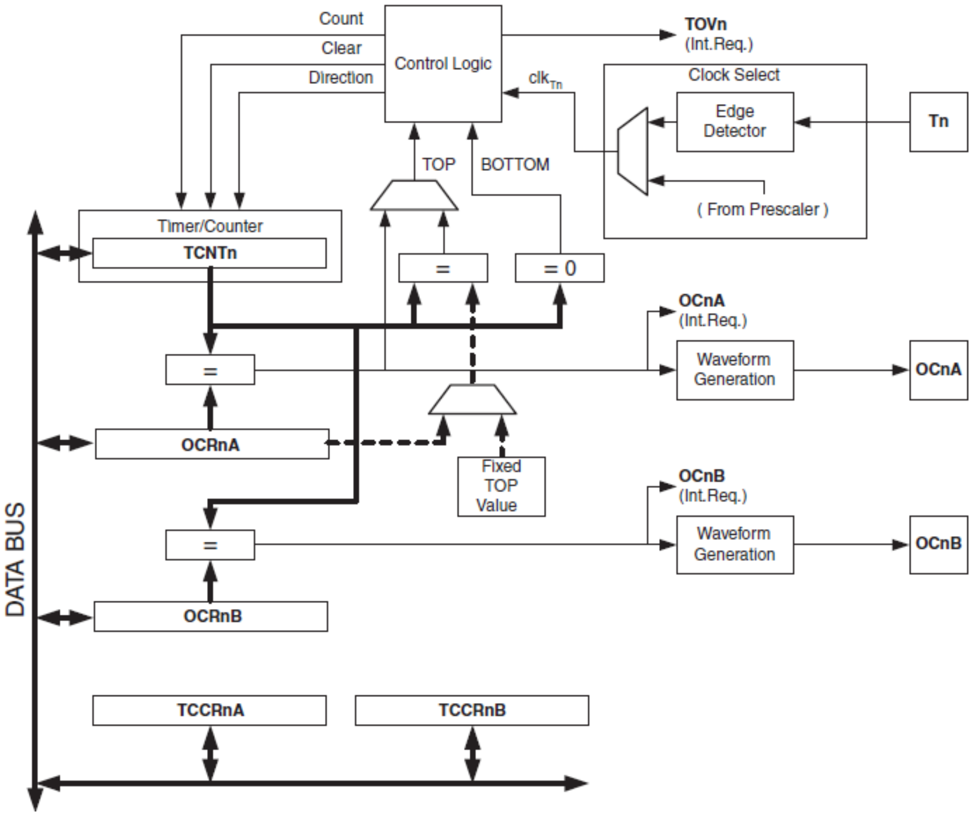

Figure 31: 8 bit timer/counter schematic[1]

As shown in Figure 31 the counter can also use 8 bit registers called OCRnA and OCRnB. These can be used to trigger interrupts when TCNTn = OCRnA or OCRnB. The Tn input can be configured as an internal or external clock. If you use the external input, counter 0 has its input on pin 7 on Port D.

The following registers are used to set up the counter:

- **GTCCR – General timer/counter control register**
  This is the general set-up for the counter, prescaler and configuration of the synchronization between these two. No configurations were done in our application.
- **TCCR0A and TCCR0B – Timer/counter0 control register A and B:**

These registers contain the bit setting values:

- COM0A1;COM0A0;COM0B1;COMB0:
  These are all in TCCR0A. The values can be used to set an output high when either OCR0A or OCR0B = TCNT0. These outputs require that their respective pins have been set as outputs (DDRx). We don't use this configuration in our application.
- WGM00;WGM01;WGM02:
  These values can be found in both TCCR0A and TCCR0B. These bits control the reset settings of the counter and how it will work. Figure 32 shows how these can be used for different operations. We will not explain all of them, for further information we refers to the data sheet [1].

Table 17-5. Waveform Generation Mode Bit Description

Mode	WGM2	WGM1	WGM0	Timer/Counter Mode of Operation	TOP	Update of OCRX at	TOV Flag Set on(0,0)
0	0	0	0	Normal	0xFF	Immediate	MAX
1	0	0	1	PWM, Phase Correct	0xFF	TOP	BOTTOM
2	0	1	0	CTC	OCRA	Immediate	MAX
3	0	1	1	Fast PWM	0xFF	TOP	MAX
4	1	0	0	Reserved	–	–	–
5	1	0	1	PWM, Phase Correct	OCRA	TOP	BOTTOM
6	1	1	0	Reserved	–	–	–
7	1	1	1	Fast PWM	OCRA	BOTTOM	TOP

Notes: 1. MAX = 0xFF
2. BOTTOM = 0x00

Figure 32: WGM00;WGM01;WGM02 modes of operation[1]

The TOV flag is also shown in Figure 31. This flag is set according to configuration. For our application we have chosen to set WGM00, WGM01 and WGM02 low. This means that the TCNT0 will not be reset until it reaches its top value 255. When a match occurs between the OCRA0 and TCNT0 or OCRB0 and TCNT0 it will not reset the counter value. If we have chosen CTC as settings, the counter value would have been reset when OCRA0 = TCNT0.

- FOC0A and FOC0B:
  These two bits can be found in the TCCR0B register. These bits can “force” an output for OCRA0 or OCRB0. We do not use these in our application.
- CS02;CS01;CS00:
  These three bits control the input, whether it's an internal or external clock source that is used as input. We are using an external input and this is configured to trigger on rising edge, CS02:00 is set high.
- **TCNT0, ORCOA and OCROA:**
  These are the value registers for the counter and the two compare values. We can access these if we want to change their values.
- **TIMSK0 – Timer interrupt mask registers:**
  This is used to enable the interrupts for the comparison A, B and overflow interrupt. All of this are enable in our application.
- **TIFRO – Timer/counter0 interrupt:**
  This is the flag register. Each interrupt is set high and reset by hardware.

In order to reduce power, the ATmega128RFA has configurable registers which allows different hardware and functions to be shut down. This comes in addition to defining the digital pins. The registers which are used to control power consumption are:

- SMCR: Sleep mode control register, no changes made.
- PRR0: Power reduction register 0, changes made.
- PRR1: Power reduction register 1, changes made.
- PRR2: Power reduction register 2, no changes made.
- TRXPR: Transceiver pin register, no changes made.
- DRTRAM0-4: Data retention configuration register, no changes made.
- LLCR: Low leakage voltage regulator control register, no changes made.
- LLDRH: Low leakage voltage regulator data register (High-byte), no changes made.
- LLDRL: Low leakage voltage regulator data register (Low-byte), no changes made.
- DPD 0-1:LLDRH:Low leakage voltage regulator data register (High-byte), no changes made.

SMCR:

This register consists basically of 4 changeable bits which could change the state of the ATmega128RFA1. Enabling these bits will activate different power save modes. SMCR is not configured in this application.

PRR0:

Bit 6 - PRTIM2 - Power reduction timer/counter2:

Timer/Counter2 isn’t used in our application and will be disabled.

Bit 3 – PRTIM1 - Power reduction timer/Counter1:

Timer/Counter2 isn’t used in our application and will be disabled.

This will give the following register value:

PRTWI	PRTIM2	PRTIM0	PRPGA	PRTIM1	PRSPI	PRUSART0	PRADC
0	1	0	0	1	0	0	0

PRR1:

Bit 6 – PRTRX24 - Power reduction transceiver:

This could be turned off for this prototype application. However this will be used to communicate with the existing micro controller on the TC2. Although we probably won't be able to develop a communication protocol, this will be active so the power consumption will be approximately correct.

Bit 3-5: PRTIM3-5 – Power reduction timer/counter3-5:

Timer/Counter3-5 isn't used in our application and will be disabled.

This will give the following register values:

Res	PRTRX24	PRTIM5	PRTIM4	PRTIM3			PRUSART1
0	0	1	1	1			0

PRR2:

This register could be used to turn off SRAM blocks 0-3. PRR2 is not configured in this application.

TRXPR:

Enables control of the radio transceiver, like reset or state transition. TRXPR is not configured in this application.

DRTRAM0-3:

These registers handle the behavior of SRAM blocks 0-3. Power settings will not be configured in this application.

LLCR:

This register handles the configuration of the low-leakage voltage regulator. This will be set to automatic when not changed. We will not configure this register in this application.

LLDRH and LLDRL:

Changes on these two registers will change the output voltage of the low-leakage voltage regulator. We will not configure these registers in this application.

DPDS0-1:

Both of these registers sets the maximum output currents for all ports on ATmega128RFA1. The output current can be set from 2 mA to 8 mA. We don't need more than 2 mA so these registers will not be configured in this application.

STK600

Figure 33: Picture STK600[21]

The STK600, illustrated in Figure 33, is an evolution board that can be used to develop software and tests. The rated voltage supply is 10 – 15 V. This can be done with a 230 V adapter. It is also possible to use the USB interface as a voltage supply. In our application it is powered by the voltage regulator, which delivers 12 V. The card is equipped with pins that are connected to the ports on the ATmega128RFA1. The card also has 8 switches and 8 LEDs. Switch 0 and 2 is used in our application.

PRICE LIST

This chapter will present the material costs for the prototype. For more details of all our costs through the project, see "Budget" (D-08.A.13-A). If the price is zero, it means that we have borrowed it from our employer for free.

ELECTRICAL PARTS

Manufacture	Product	Price (NOK)
Atmel	STK600	0,00
Atmel	ATmega 128RFA1	0,00
Biltema	Power switch and div. components	134,60
Clas Ohlson	Serial cable	79,00
Elfa	DAC	80,25
Elfa	Op-amp	19,19
Elfa	5V voltage reference	57,85
Elfa	12V voltage regulator	6,71
Elfa	Expedition/fee	116,00
Eltex of Sweden	G3w - weft sensor (incl. moms)	1344,75
Exmec	Motor for gripper arm	0,00
Faulhaber	Motor for thread selection	0,00
Fulling motor	Motor controller for Exmec motor	0,00

MECHANICAL PARTS

Manufacture	Product	Price (NOK)
Bauhaus	Casing (plywood, screws, nuts)	462,97
Bauhaus	Thread holding/feeding (Threaded rod and hooks)	82,00
Biltema	Gripper arm (measuring tape, sandpaper, scissor, pliers)	312,20
MJS	Sheet metal	N/A
SDP/SI	Drive wheels, belts, bearings etc.	1429,13

This gives a total of around NOK 4000,-. In addition to this, it must be expected expenses for the motors and motor controller, microcontroller, and production of the sheet metal.

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DISCARDED DESIGN AND ANALYSIS OF “AUTOMATIC SHUTTLE CONTROL SYSTEM”

D-00.B.23-EM

Release 2.0

RELEASE NOTES

Date	Version	Description	Author
09.02.2012	0.1	- First draft	Eirik Nordstrand
21.02.2012	0.2	- Fixed up the mess-up	Eirik Nordstrand
22.02.2012	0.3	Edited chapter on module 23 and added text	Andreas Stustad
07.03.2012	0.4	Edited and updated chapter 23	Andreas Stustad
09.03.2012	0.5	Added information about module 12 Added information about module 20 Edited figure references Updated tables and figure numbers	Mats Strand Sætervik
13.03.2012	0.6	Prototype	Andreas Vander
13.03.2012	0.7	Added information about module 11 Added information about module 12	Vazgen Karlsen
14.03.2012	1.0	Finalized document	Eirik Nordstrand
20.04.2012	1.1	Added discarded technology	Mats Strand Sætervik
02.05.2012	1.2	Redefined and added information on in "Feeding mechanism for gripper arm"	Mats Strand Sætervik
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ABOUT THIS DOCUMENT

This document contains our discarded research for the different modules at the loom. It describes the solutions and discussing advantages and disadvantages for the different discarded solutions.

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INTRODUCTION

This document describes the discarded solutions and proposals we have made for making the final solution for a prototype, which is explained in the document “”design and analysis” (D-00.A.18-EM). These discarded solutions are discarded for various reasons, and this will be explained under the actual discarded solution. This document is divided into modules or sub-systems, in numeric order. The discarded solutions are later divided into mechanical, electrical and technical solution, with pictures to illustrate the solution or proposal.

MECHANICAL DISCARDED SOLUTIONS

GRIPPER HOOK SUPPORTED

The cons with the gripper hook were the instability. Because it is slim it will twist easy, as we did discover on the Lego prototype. A possible solution for this problem is to support the gripper so that it will not twist. The cons with this idea are that the contact area with the warps is larger and will result in more friction, and the weight of the gripper will be larger. Another problem is the size. The gripper will be wider to be supported, and space is very limited (described in “Total storage space” D-00.A.10-EM). Supported gripper is illustrated below in Figure 1.

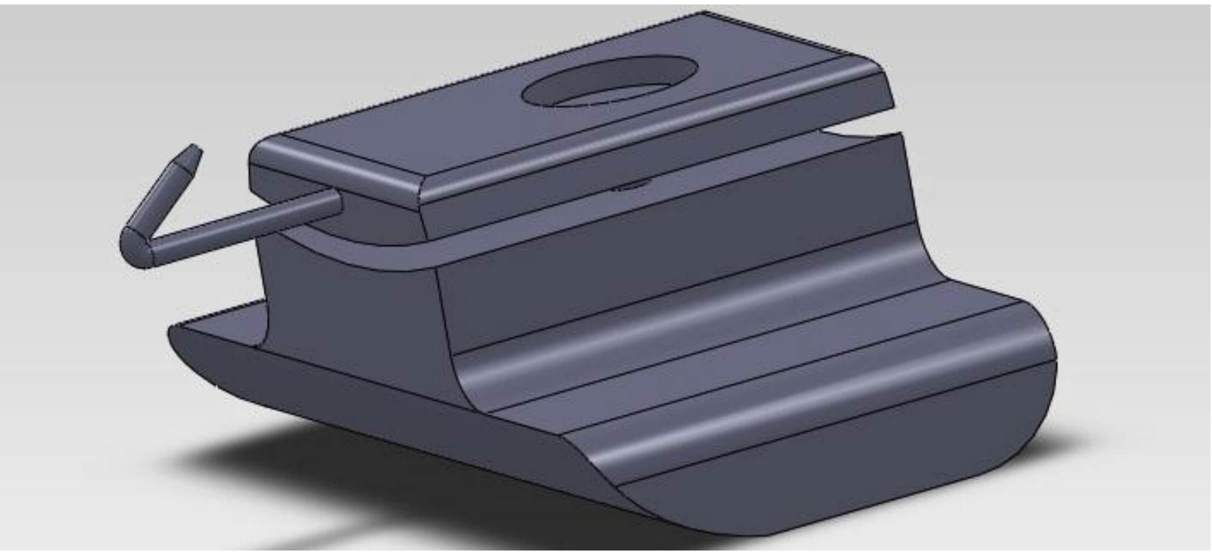


Figure 1: Gripper hook supported

MECHANICAL GRIPPER

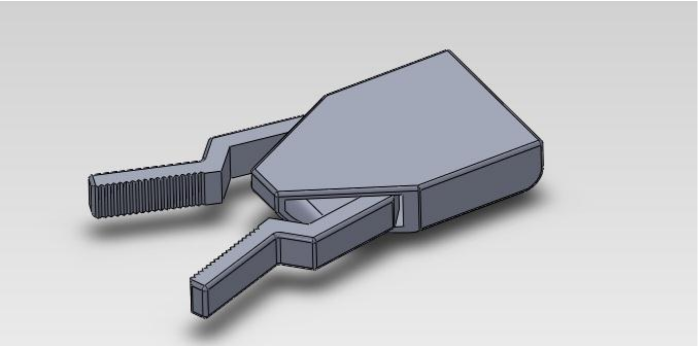


Figure 2: Mechanical gripper

If we choose to go for the revolver solution (see chapter about thread selection), facing the shed, we will have to use a mechanical gripper that is very precise. The mechanical gripper, illustrated in Figure 2, will snap together when passing the thread. The function will be triggered by the gripper hitting an object on its way into the thread selection system. On the way back to its "garage" it will hit another object and unfold and release the thread. There are many problems facing the revolver solution and also the mechanical gripper. This solution has more or less been discarded.

MODULE 11: GRIPPER ARM

MECHANICAL SOLUTION

MATERIAL, SHAPE AND POSITION

We have looked at solutions for what types of material and shape the gripper arm will be made of. Through a brainstorming evaluation process that included debates regarding size, noise and available space, the group has decided to pursue one solution. The solution we want to explore is to develop a gripper arm that has the same characteristics as a measuring tape. This solution is also used in the Lego prototype.

Cable chain, as illustrated below in Figure 3, was the first solution we looked into. This was because Tronrud Engineering suggested it.

Figure 3: Cable chain

There were several positive and negative sides about this solution:

Positive:

- Cheap
- Different shapes and sizes
- Would not slip

Negative:

- Difficult to store
- Difficult to feed
- Makes noise

The first solution of storing the gripper arm that we had chosen as current solution was to roll it with internal clock spring. That solution got discarded through technology analysis where we found that the spring would have a very limited life circle. This solution is illustrated in Figure 4

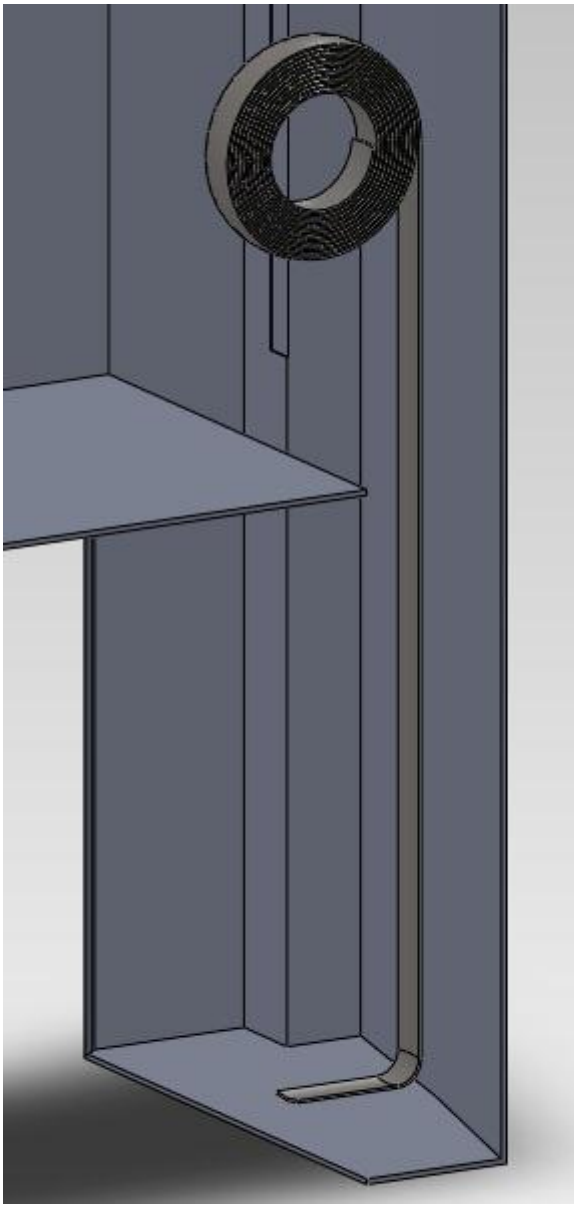


Figure 4: Gripper arm stored as a roll

As the group sees it, there are three possibilities for placing a motor, illustrated in Figure.

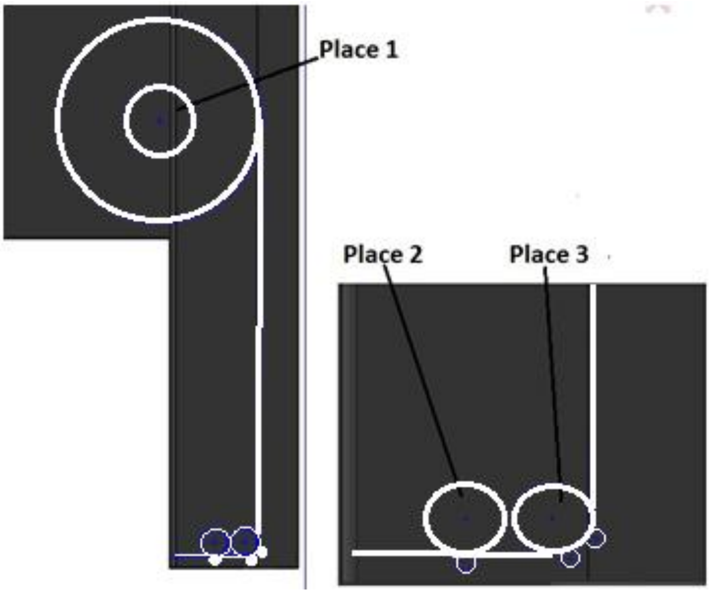


Figure 5: Places to fit motors

Place 1:

Positive:

- More available area to place for the motor - the motor can be bigger.
- Frees up more space for the shuttle in the lower area.
- More space to place possible transmission and drive train.
- Enough room to use a bigger drive wheel. This allows a less maximum rpm to reach the gripper's max speed.

Negative:

- The force by the motor is applied directly to the “spooled up” gripper arm. When the gripper arm changes its direction (90̊) at the bottom, the force may bend the arm.

Place 2:

Positive:

- The size of the drive wheel can be adjusted.

Negative:

- The force applied by the motor may bend the gripper arm when it retracts the shuttle.
- Maximum brake force is limited by the friction force between the drive wheel and the gripper arm.

Place 3:

Positive:

- Hopefully this location will eliminate the problem that the gripper arm may be bent.

Negative:

- The drive wheel size has to match the radius of the arm that has to be bent.
- High probability that the drive wheel got to have a small diameter, which means that the motor needs high rpm to reach top speed of the gripper arm.
- Maximum brake force is limited by the friction force between the drive wheel and the gripper arm.

MOTOR TYPES

The group has two solutions for how the power can be transferred from the motor to the arm:

- **Circular movement:**
  The motor drives the arm directly (or through gears), and the circular movement (number of revs and angle) of the motor defines how far the gripper arm goes. In other words, the motor has to be stopped at each end of the shed. This solution is used in the Lego prototype.
- **Circular to linear to circular movement:**
  The motor drives a "piston" which powers the gripper arm. To simplify, x number of revolutions by the motor in the same direction drives the gripper arm the length of the shed and back again. This way the motor only has to move one way and it's only necessary to slow the motor down when the gripper is approaching its start position again. This solution is only possible if the gripper can travel the same length every time. This solution will probably be cheaper and demand less precise control of the motor.

After we have done some research and done some tests with our prototype, we have set some properties that our motor must have:

- Good start torque:
  The motor needs this to achieve good acceleration "instantly" because of the little timeframe and distance the gripper travels.
- Good position/speed control:
  The position of the gripper is controlled by the motor. Rapid acceleration and stopping is necessary to make the time travelling demand.
- Good durability and "dust resilient":
  The motor has to perform many repeatedly cycles and is being placed on a device which moves threads which develops dust.

To show the process we have gone through to determine how to power the arm, we have this table:

Attribute	Circular movement	Circular to linear movement
Starting torque	Can be high, but will then decrease the maximum speed	Same as circular movement
Positioning	Very good, as long as the slip is minimal. Requires regulation	Hard to hold other positions than the end points. But requires no regulation, will hit same end point each time
Speed	High	Depends on the piston, but higher speeds requires more force to be put on the piston
Durability and dust	High durability, somewhat exposed to dust	Little durability, because of forces on the piston

So the solution for this project is to use gears, not a piston, mostly because the gearing gives a possibility to regulate the arm in real-time if slip occurs. If slip occurs on the piston solution, the system will be out of sync and then the system might propel the gripper into a wall on one of the sides. This may result on a catastrophic crash and the destruction of parts in the system.

SENSOR NEEDS

The gripper arm and gripper needs the following tasks covered by sensors:

- **Position:**
  The position of the gripper arm is necessary to control the gripper arm movement and to know where several other modules need to act, for example when the thread has to be released.
  We will try to accomplish acceptable control without a position sensor. The position of the motor will be used to calculate/find the position of the motor.
- **Free path:**
  We need sensors that can detect if there is something in the gripper path. This needs to be done because the gripper may be damaged or can do damage to anything in its path. When we visiting Tronrud Engineering the second time, a TC2 was observed while weaving. It then becomes clear that because of the small clearance between the treads, a implanting of sensor solution could be hard to fulfill.

SENSOR SOLUTIONS

Position:

- **Incremental sensor:**
  This sensor will be connected to the driveshaft powered by the engine. The pulses provided by this sensor will be used to calculate the gripper arm's position. These may be sensitive to dust and dirt, and therefore not suitable for our application.
  Example of an incremental sensor can be found here [1].
- **Inductive or HALL sensor:**
  These can be used to indicate a reference point for the start and position of the gripper; “a count of pulse” starter. These will be zero point indicators for the grippe arm path.
  We could also use an inductive sensor to create our own position sensor. We can use an inductive sensor and make this sense on a metal wheel with holes. The ME060AS has hall sensors, which the motor driver uses as inputs to generate pulse outputs.
  Example of an inductive sensor can be found here [2].

Example of a HALL sensor can be found here [3].
We have not included an absolute encoder because we think this will be too expensive and it won't be necessary with the "zero" position sensors.

Free path:

- **Photo sensor:**
  We think the best solution for this is to use an optical encoder that can detect if anything gets in the way of the gripper arm's path.
  Example of an optical sensor can be found here [4].

Positioning is now mostly done by the controller for the gripper arm (see chapter "Module 12, electrical solution"), but there is still the problem with slip, and therefore the arm needs a sensor or two for checking end points. The "free path" sensors has been discarded due the extremely small space between the warps and after wished to limit the use of sensors from Tronrud Engineering

MODULE 12: FEEDING MECHANISM FOR GRIPPER ARM

MECHANICAL SOLUTION

This "flat wheel" solution is very similar to the current solution. There are several reasons that made it discarded:

- There were some parts that were difficult to produce.
- The design could be done simpler by reducing amount of parts
- There was a technical problem that is described closer below

As illustrated in Figure 6 below, every wheel had a flat shape. That would flatten out the measuring tape that is the current solution for the gripper arm. There were also two shaft diameters that resulted to two different bearing dimensions.

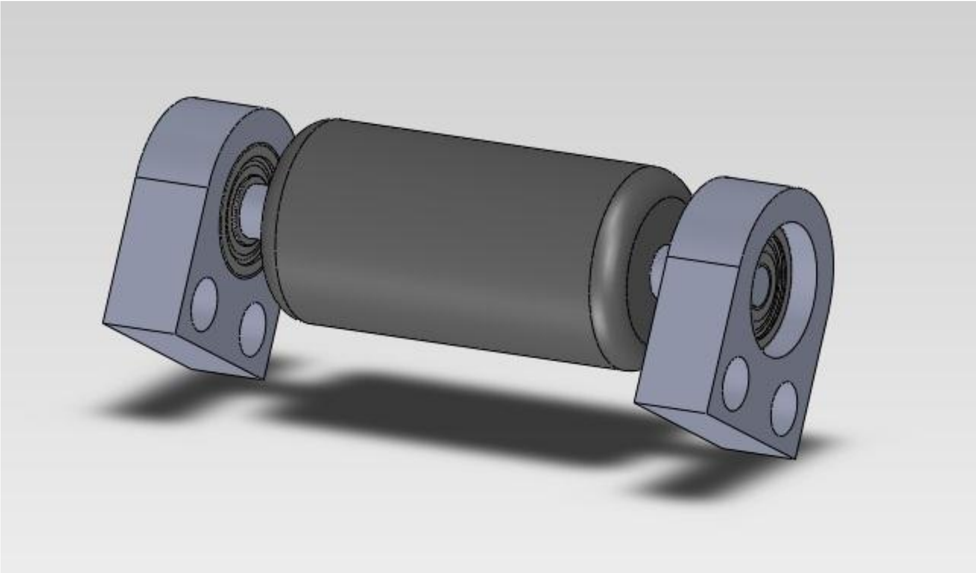


Figure 6: Flat wheels

ELECTRICAL SOLUTION

HARDWARE

Speed controller Fullingmotor 24ZWSK-05-S:

This speed controller couldn’t be used; the motor was drawing a great amount of current when rotating counterclockwise. We thought the reason for this was because it was delivered with a production fault. The producer confirmed that this problem was the result of a production error discovered 9 months earlier, but we had also connected the phase wires wrong.

This controller was also has a 4 pole controller, while we have an 8-pole motor. Originally this wasn’t considered as a problem because it was believed that this only would affect the speed and torque, which would have been sufficient anyway.

Data sheet can be found on the CD, under Attachments→Feeding mechanism for gripper arm→ Data Sheets controllers and components →“AllMotion_ZWSK_BLDC_drives”.

We thought the best solution would be to use position control to control the gripper arm. Position control would allow us to get control of the engine output torque, speed and position. The group felt this was necessary because:

- The gripper has to stop within +/- 5 mm of the set point. Missing this position will result in that gripper would stop in front of the beater, hit wall in the thread selection module or hit the pulley wheel of the feeding mechanism for the gripper arm.
- Earlier estimations (See technology document (D-00.A.17-EM)) indicated that the gripper had to travel at high speeds and accelerate and decelerate rapidly.
- Torque control would allow us to determine the output torque of the motor. This would decrease the risk of slip between the pulley wheel and the gripper arm. Too high torque would lead to an incorrect position reading of the gripper arm.

Several distributors where looked into to find a suitable controller. Some of them were:

- Maxon motors.
- Technosoft motion technology.
- Transmotec.

Technosoft motion technology had the most suitable position controllers. Theses could be programmed by dedicated software (Easymotion Studio[5]) or for example with library files in program such as Microsoft Visual Studio. An example of a Technosoft intelligent controller can be found here [6]. An intelligent controller would cost around 3000,- NOK and a single user license for EasyMotion studio costs 3000,- NOK.

Discarded reasons:

- Discarded with advice from employer. The intelligent controller is quite expensive and we have to try with a speed controller first to investigate whether or not this will accomplish the task. It was also pointed out that if we couldn't achieve a travel time of total 1 second, we should increase the traveling time. It's more important to prove that the design principle is working, than trying to meet a high requirement and totally fail.

Developing a control algorithm for the motor was seen as to much work and not necessary to accomplish desirable control.

In order to regulate the motor and simulate the motions and precision, the group will develop a program in Matlab that will be used to develop the program algorithm for the controller.

The program is under development and can be accessed under Attachments →Feeding mechanism for gripper arm→Matlab→Speed controller.

The Matlab program develops a trajectory according to data for the motor and load.

Motor data:

```
%ME060AS101 motor data:
Vs = 24;                    %Supply voltage (V)
W_motor = 3000*2*pi/60;     %rad/s
R = 0.56e3;                 %Resistance (Ohm)
L = 6.5e-4;                 %Inductance (H)
Kb = 4.25e-3;               %Back EMF constant (V/rpm)
J = 4.5e-5;                 %Rotor inertia (kgm^2)
KT = 0.5;                   %Torque constant (Nm/A)
f = 0.009;                  %Friction coefficient
```

In addition to this torque load, top speed, acceleration and deceleration time were given:

```
%INPUT VARIABLES:
Q_f = 22.5*pi*2;            %Is the nuber of pulses  want to reach, end
posistion
W_max = 300;                %rad/s
Tl = (0.22-0.1263);         %Torqueload (Nm)
```

The trajectory generation is based on that the acceleration and deceleration time is equal:

```
%TRAJECTORY GENERATION
t1 = 0.1;                   %Time motor accelerates(Excel)
t2 = Q_f/W_max;             %Adapted to fit W_max=Q_f/t2
t3 = t1+t2;                 %Time motor accelerates, travel at
%constant spees and decelarate
W_max2=Q_f/t2;              %rad/s
```

By running the program we developed the constants c1 and c2 which was supposed to be used as constants in the final program. The trajectory would look something like this, which gave us the speed, acceleration and position reference:

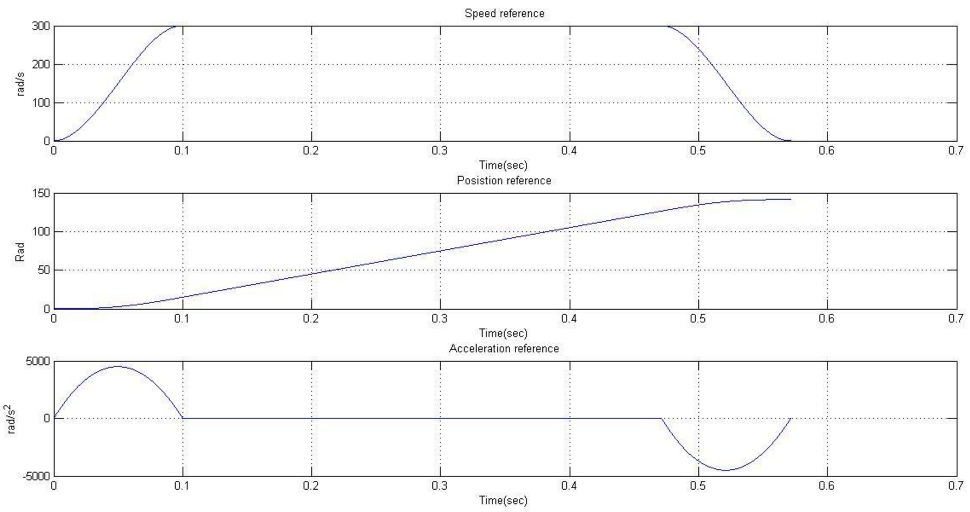


Figure 7: Speed, position and acceleration reference

DC-DC CONVERTER

The use of DC-DC converters from 12V to 24V were original considered because we were advised by OEM Drammen not to use 12 V motors. There were also problems with finding distributors that could deliver 12 V BLDC motors that could fit the TC2. When we discovered that Transmotec could deliver 12 V BLDC motor that would fit and produce enough torque,

The decision to discard the use of a DC-DC converter in order to use 24V motors were made by the group because using one to power on or several DC motors was going to be too expensive.

MODULE 14: PCB

Some components have been discarded for our solutions, these components will be described here and why they were discarded.

DAC – AD7524

This part was ordered and tested. The test however made it clear that this component didn't work like we intended it to work. A misunderstanding when reading the datasheet, let to that this component had to replaced by AD558.

Connections on AD7524:

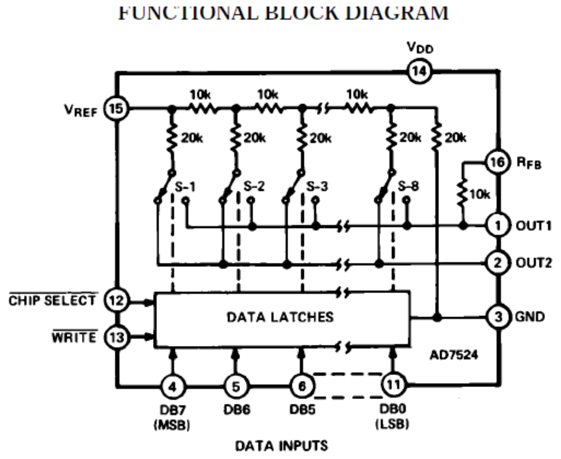


Figure 8: Functional block diagram, AD7524[7]

The connections where wired as followed:

Vref -> Output REF02.

DB0-DB7 -> Line 0, Port 0-7 on Ni USB 6008.

Write -> Line 1, port 0 on Ni US 6008.

Out 2 -> Gnd

Out 1 -> Non-inverting input on LMC6041.

The DAC didn't work as planned. The main problem was detected when the datasheet were examined a second time. It was believed that the only external component needed to make this work, was an external amplifier (LMC6041) and a voltage reference (REF02). A table from the datasheet explains the problem:

ANALOG CIRCUIT CONNECTIONS

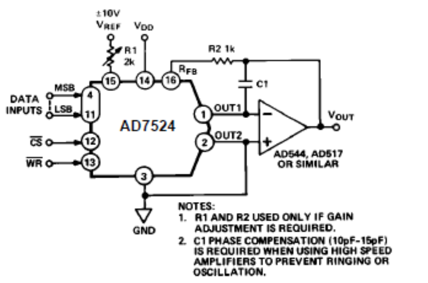


Figure 4. Unipolar Binary Operation (2-Quadrant Multiplication)

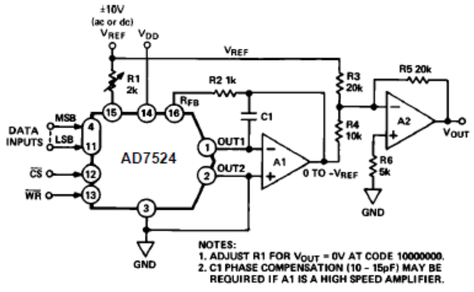


Figure 5. Bipolar (4-Quadrant) Operation

Table I. Unipolar Binary Code Table

Digital Input MSB LSB	Analog Output
1111 1111	$-V_{REF}$ (255/256)
1000 0001	$-V_{REF}$ (129/256)
1000 0000	$-V_{REF}$ (128/256) = $-V_{REF}/2$
0111 1111	$-V_{REF}$ (127/256)
0000 0001	$-V_{REF}$ (1/256)
0000 0000	$-V_{REF}$ (0/256) = 0

Note: 1 LSB = $(2^{-8})(V_{REF})$ = 1/256 (V_{REF})

Table II. Bipolar (Offset Binary) Code Table

Digital Input MSB LSB	Analog Output
1111 1111	$+V_{REF}$ (127/128)
1000 0001	$+V_{REF}$ (1/128)
1000 0000	0
0111 1111	$-V_{REF}$ (1/128)
0000 0001	$-V_{REF}$ (127/128)
0000 0000	$-V_{REF}$ (128/128)

Note: 1 LSB = $(2^{-7})(V_{REF})$ = 1/128 (V_{REF})

Figure 9: Circuit connections , AD7524[7]

Figure 9 shows that the analog output will give the negative reference voltage. It was concluded with that this circuit would best work with negative voltage, there were discovered circuits that could have worked without negative voltages, but these were concluded not suitable for our applications. This DAC was replaced with AD558.

VOLTAGE REFERENCE – REF02

The voltage reference REF02 was meant to work as a voltage reference for the AD7524. When the AD7524 was replaced with AD558, the REF02 was no longer necessary. The component was tested, and the test was approved.

Figure 10: Voltage reference output

The voltage reference where wired accorded to datasheet[8] and the Fluke showed 4,998 V. No load was applied.

OPERATIONAL AMLIFIER – LMC6041

This rail-to rail operational amplifier was intended for the voltage follower circuit. This operational amplifier stopped working after it was wrongly wired during a test with the ATmega128RFA1. The only test that was done on this component, was to check if could operate rail to rail. The LMC6041 was replace with the CA3130 which is cheaper and has a better slew rate. Figure 11 shows the LMC6041 voltage output, when 0 V where applied to the non inverting input.

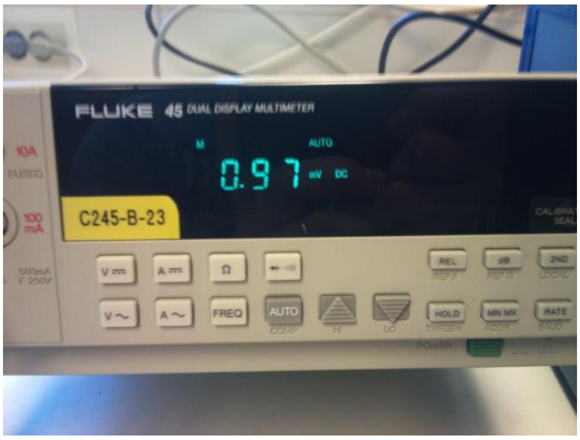


Figure 11: Operational amplifier LMC6041 voltage output

REVOLVING THREAD SELECTION

This solution, illustrated in Figure 12, is based around a revolving cylinder. The cylinder has a hole, or a "lane", for each thread. The holes will be evenly distributed around the cylinder, parallel with the rotation axis. The holes will be placed with a 45 degrees distance from each other.

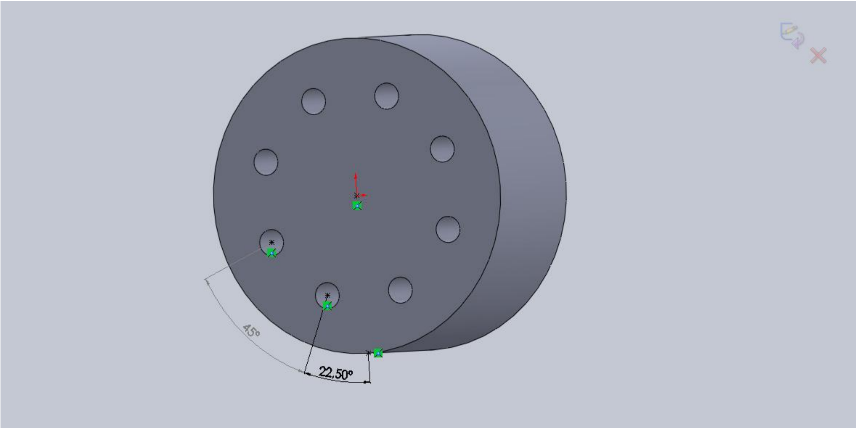


Figure 12: Revolving cylinder

The bottom point is the "zero-position". That's the revolvers starting position. This position can be marked by a sensor on the top of the cylinder (180 degrees from the "zero-position"). This will make the system to know when the revolver is at the starting position. The main point of this design is to minimize the slack on threads that's not in use, and place the selected thread at the same location each time. The cylinder will not rotate more than 157 degrees from "zero-position".

$$157{,}5° = 180° - \left(\frac{45°}{2}\right)$$

The rotation restriction is so the threads do not interfere with each other, get twisted or get hung up in other components.

The selected thread will then be placed at the bottom. This gives three alternative pickup solutions, the revolver facing the shed, parallel with the shed and facing down. All solutions is described below.

REVOLVER FACING THE SHED

The revolver will be facing the shed. This will eliminate the need for tensioning the selected thread, but will set high requirements for the gripper and cutting mechanism. The thread will just be hanging from the revolver and will be hard to pick up. This will require that the thread has to lie “far” outside the hole. With all the threads in the revolver hanging “far” outside, the problem with thread twisting occurs. If we see past this problem, the gripper and the cutting mechanism will still be a problem. The gripper needs to be mechanical and very precise, with an arm feeding mechanism that’s equally precise as feeding length of the arm. The cutting mechanism has to be very big, since it shall not block the path of the gripper and shall be able to cut the selected thread.

REVOLVER PARALELL WITH THE SHED

The next solution is having the revolver facing the user. The main issue with this solution is space. If the revolver is facing the user with its front side, the space for the motor that controls the revolver is very limited and the space has to be shared with the threads. That if the axis from the motor is directly connected to the revolver. If the motor is connected by a belt or a chain, we will lose precision on the revolver. The revolver can also be placed facing its backside towards the user. This gives more space for the motor and thread holding, but gives less space for the cutting mechanism.

Both of these solutions set the selected thread 90 degrees on the arm, and we will therefore need a tensioning mechanism. This mechanism has to be placed on, or right beside, the cutter. The “fetching” device has to move in two axes, one to move towards the revolver, and then grip the selected thread. Now the selected thread is tensioned and ready for pickup.

REVOLVER FACING DOWN

This solution idea uses gravity as a way of “tensioning” the threads. The issues are then that all the threads from the revolver hang downwards. That means that this idea gives the same high requirements as if the revolver were facing the shed. Other problems with this idea are that we rely on gravity to hold the threads straight down.

The common issues with this solution are thread handling behind the revolver. With the current idea with revolver, the threads will be mounted in a smaller stationary revolver behind the selecting revolver, to minimize the slack. The slack will still occur, and therefore the system needs a device that pulls the threads back on the spool or something like a “buffer” mechanism. Another issue is the requirements this solution sets on the gripper and cutter.

The biggest issue with the revolving solution is the position precision of the selection revolver. It might seem like a stepper motor is the way to control the revolver, but error in the stepping and things like power failure is a problem. Without the “zero-position” sensor, the revolver is rotating blindly. An example is if power failure occurs and the rotor is not in “zero-position”; then how does the system decide which way to turn? One way is to physically hinder the revolver from turning over its boundaries. The other way is to use an absolute encoder. The absolute encoder will always give us the position of the rotor, but it’s very expensive. The encoder can also be designed to fit our needs, but it’s a high probability that this will be very time-consuming and the result may be poor.

This idea will be based around that each thread will have its own "pendulum" and "hold-cut" device. This eliminates slack on unused threads, like the revolver will have. This idea is also using the available height more efficient.

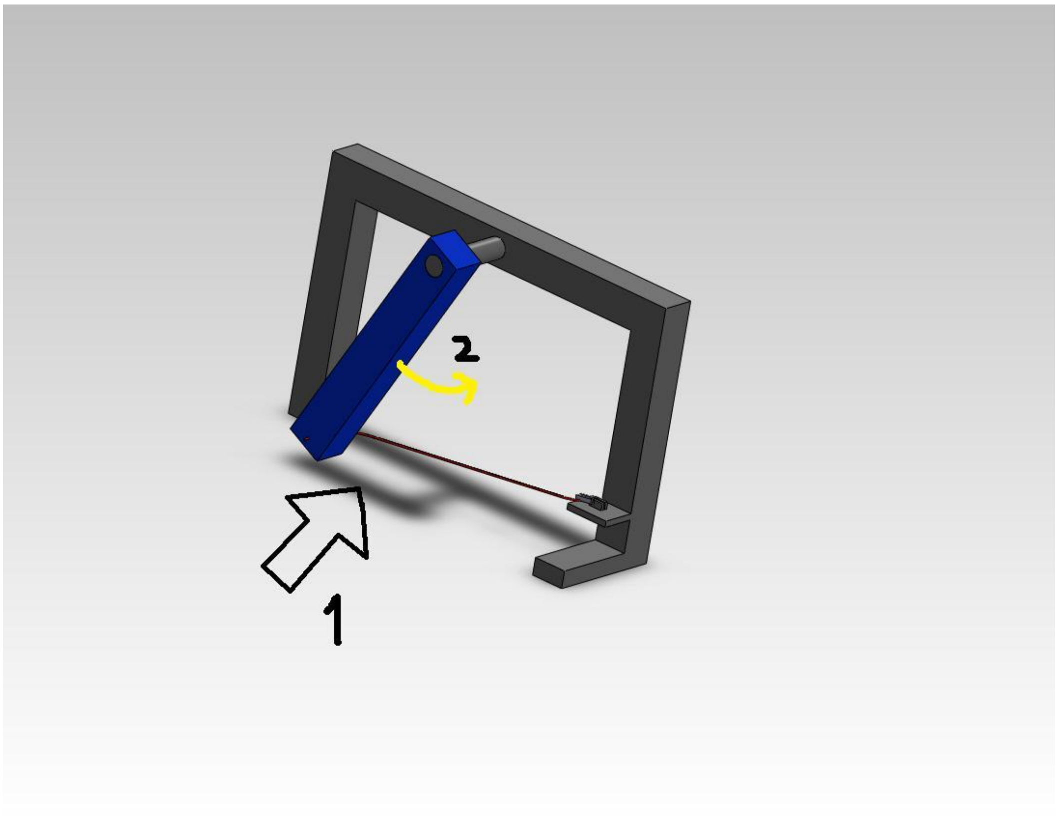


Figure 13: Pendulum design

Figure 13 above shows the idea, but only implemented with 1 thread selection unit. Each unit contains a pendulum, cutter and a holding mechanism. On the figure, the arm (marked by 2) is in "Ready for pickup" position. Number 1 marks the gripper's way into the garage. The tread will then be picked up, and laid double half the length. Then the arm moves (shown as the yellow arrow) and the first part of the thread will be released. Then the arm will pull the thread from dual lay to single. On the assumption that friction of thread lying on the warps is way smaller than the force needed to pull out more thread from the spool through the system. The holder will then close again, while holding the "end" of the thread. The thread will then be cut, and the module is ready for next selection. The idea will be to have 8 of these units after each other. This will then make a "garage", where the correct thread is picked up. This design idea is very simple and easy to implement in theory, but as stated above, we have limited space. A total of eight units will give each unit 1cm of space. This means that the construction of these units will be difficult, and has to be outsourced, at least most of it.

The problem with the pendulum is that it swings below initial position before the thread is tensioned. I.e. it has to be placed with a clearing for this.

OVERREACHING ARM THREAD SELECTION

This idea is similar to the pendulum idea, but the arm's base is placed next to the holding and cutting mechanism. Also this solution needs one unit per thread. This is one of the first ideas we came up with. One of the good sides about this idea is that it doesn’t need external tensioning of the threads. This idea works similar to the pendulum idea, with the double thread laying and resetting. The most promising thing about this idea is the possibility to have units on each side.

A drawback with this idea is that both the base and cutter/holding are placed on the same side of the garage. This means the width of arm, cutter and holding has to be decreased drastically. The major drawback with this idea is that the holding mechanism's length has to be at least as high as when the arm passes by it. I.e. if the arm is 4 cm high at the passing point, the gripper needs to be larger than 4cm when opened. This limits the length of the arm very much, and will again limit the width of the garage much. The other drawback if we pair the units up, setting them in a paired configuration of 4x2, the ground area for the units which is placed nearest the TC2 will be minimal both in width and length. The pairing of the units generates some demands to the gripper and gripper arm: they must be very narrow.

FIRST ASSEMBLED DESIGN IDEA

The first design we proposed to Tronrud Engineering were meant to fit the TC2. The finishing solution was to consist of two modules with each controlling four threads.

Components included in the design:

- SKF bearings fitted with press pass
- 2610 B BLDC motors
- 3 different specially made pulleys based on the TN10 series, with self-made flanges. Made different because we wanted to increase the engines torque through ratios.
- 1 mm wide timing belts, also TN10 (1 mm pitch).
- Self-made bearing and axel houses.

Positive design features:

- It would fit the available space on the TC2.

Negative design features:

- Many components that needed precise manufacturing increasing the work hours needed to produce the parts, and therefore also the production costs.
- Insecurity regarding whether the parts was possible to produce or not.
- Small tolerances had to be defined on the frame and bearing houses. This is because the timing belt where 1 mm wide and the pulleys where 2 mm wide. Since the power transmission is done through 2 links, small tolerances had to be set on the casing and bearing houses to ensure that the pulleys were in alignment.

Discarded reasons:

- Discarded with advice from employer. The design was too complicated, and there was many suggestions to how we could improve it. We had to make changes that simplified the design, making it easier to produce, and tried to design it so it contained more similar parts.
  All in all the design was too complicated and too expensive to produce considering this would be a prototype.

Figure 14 illustrates the first deign idea. Two of these modules where going to be mounted on the TC2 so it could handle 8 threads. The casing consisted of two sheet metal plates, one inner and one outer, that was going to be bolted together.

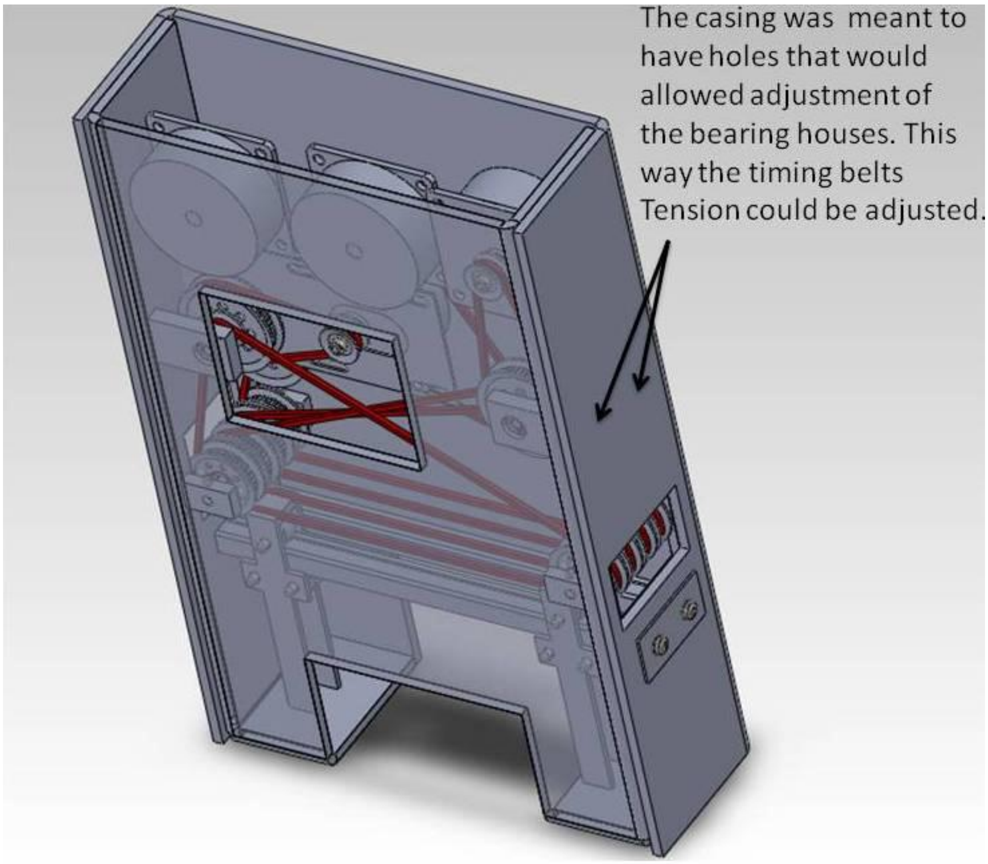


Figure 14: An overview of the first design idea

Figure 15 illustrates design with the main components. The rotational direction of the motors will result in the linear movement of the thread arms, making the thread ready for pickup.

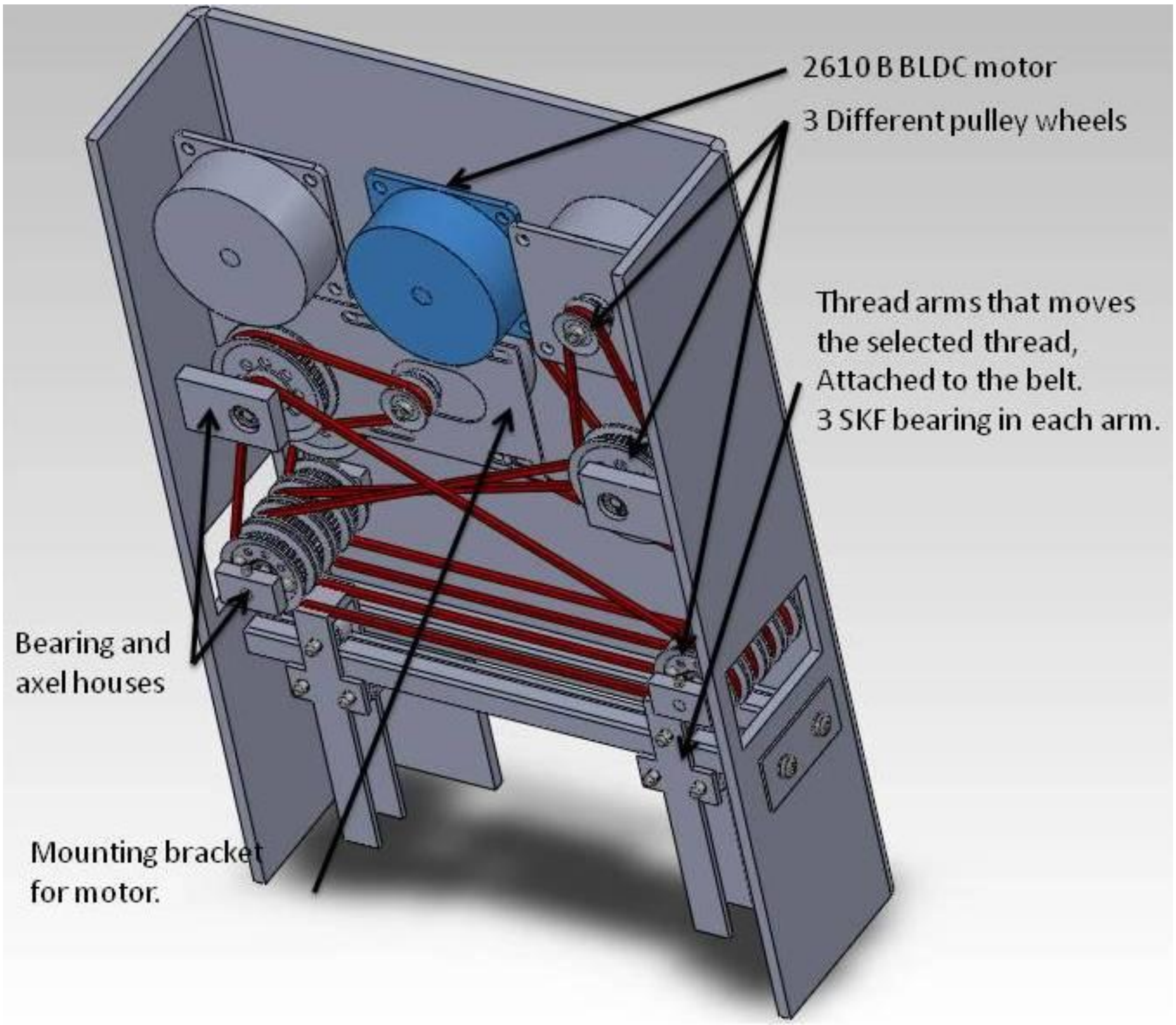


Figure 15: Illustration of components in the design

Figure 16 illustrates the lower axel containing the lower timing belt wheels.

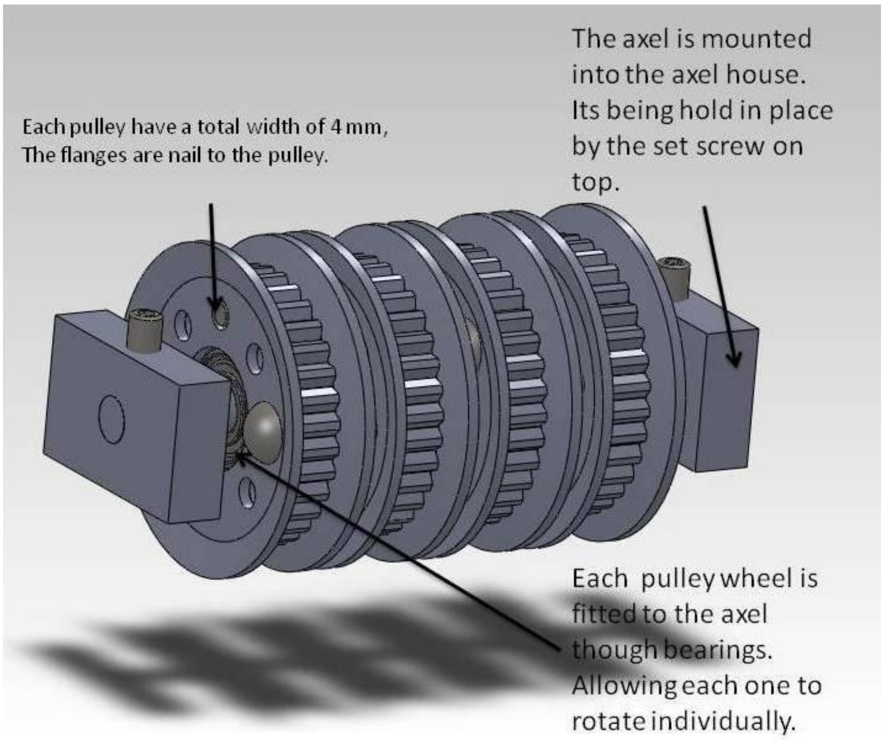


Figure 16: Illustration of lower axel assembly

Figure 17 illustrates the upper wheels, which transfer the power from the motor to the lower axels.

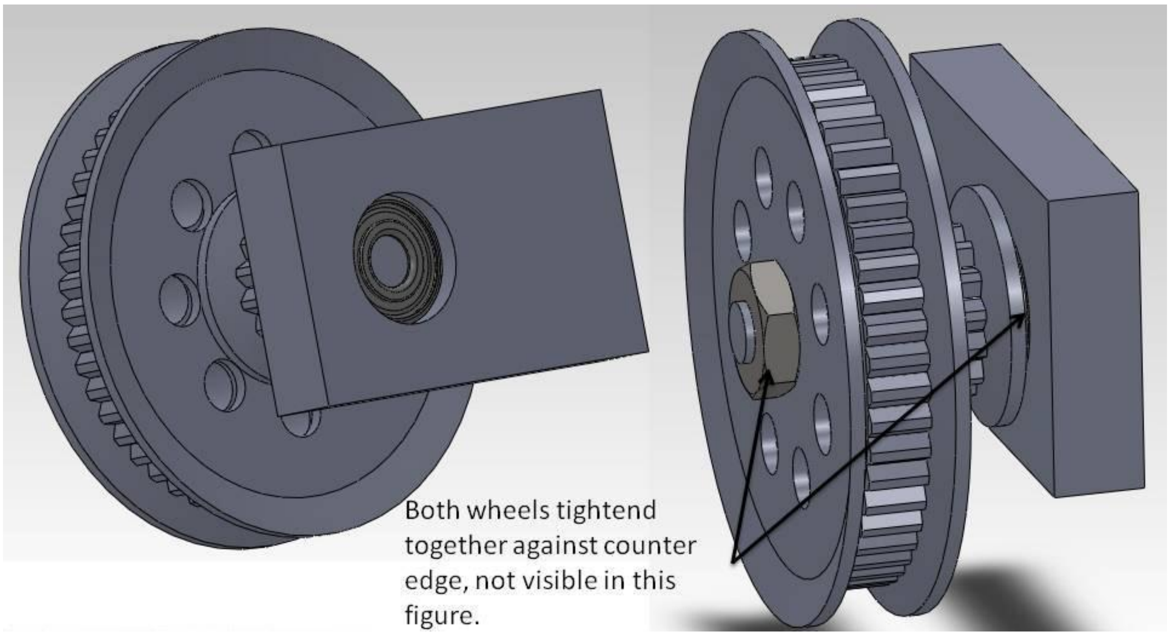


Figure 17: Illustration of upper wheels

The second design concept and solution we proposed to Tronrud Engineering fitted the TC-2. It consists of two modules, with each able to handle four threads. The main difference from the first design concept that was discarded, were the bearing and axel houses.

After some waiting time we got the pricing from OEM. OEM was going to produce our specially made pulleys based on the TN10 series. The total costs were over 8000 NOK for pulleys and timing belts for one module (able to handle four threads). After a meeting with Tronrud Engineering this solution was discarded due to high pricing of parts.

The first design we proposed to Tronrud Engineering were meant to fit the TC2. The finishing solutions were to consist of two modules with each controlling four threads.

Positive design features:

- It would fit the available space on the TC2 and be able to handle eight threads.

Negative design features:

- Components that needed to be machined from costumer's specifications resulted in expensive components.
- 1mm TN10 timing belts have long delivery time.

Discarded reasons:

- Price
- Delivery time of parts

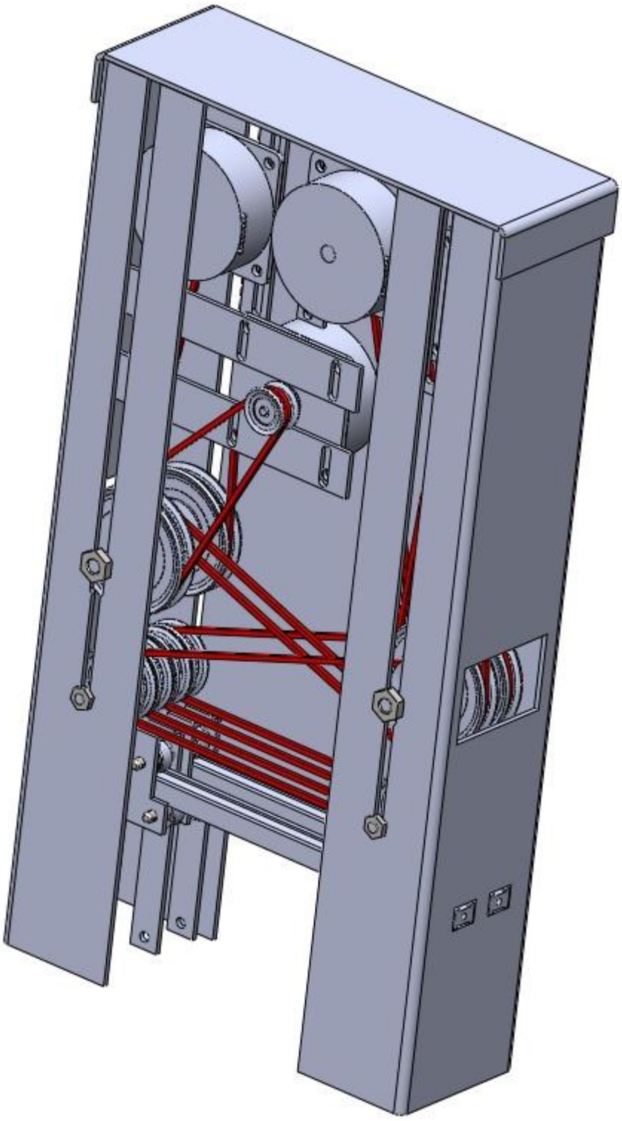


Figure 18: Second thread selection

This design illustrated in Figure 18 will consist of two modules. Each module contains 4 arms and 4 motors. The principle for the system is the same as for the moving overhead arm. The belts are of type TN10 timing belts with 1mm width and 1mm pitch. The reason why we chose this is simply because of the size. The TN10 timing belts are made of Polyurethane (PUR) with tetroncorde. The main differences from the discarded design presented at Tronrud Engineering are:

- The self-made bearing and axel house is changed to an axel (illustrated on Figure 19and Figure 21) which can be adjusted through slide tracks in the casing.
- The casing is changed from 1mm to 2mm, and it consists now only of one sheet metal plate.

PULLEY WHEELS AND AXLE

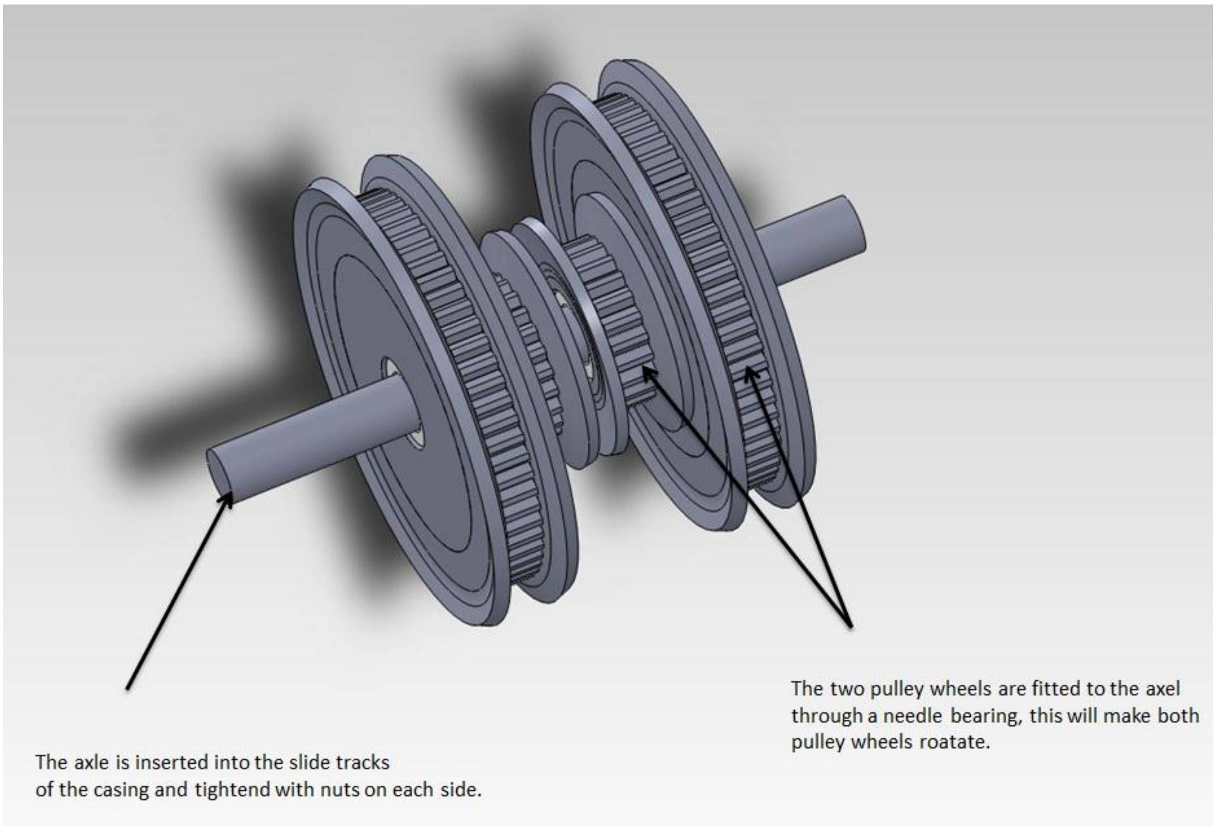


Figure 19: Illustration of upper pulley wheels

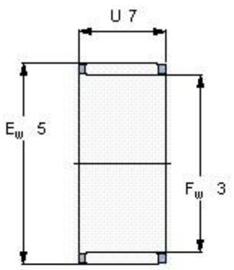
The needle bearing is from SKF with data sheet[9] on Figure 20.

Needle roller bearings, needle roller and cage assemblies

Product information

Tolerances, see text
Radial internal clearance, see text
Shafts and housings, see text

Dimensions			Basic load ratings dynamic	static	Fatigue load limit	Speed ratings Reference speed	Limiting speed	Mass	Designation	Appropriate seal Designation
F_w	E_w	U	C	C_0	P_u					
mm			kN		kN	r/min		kg	-	-
3	5	7	1,51	1,34	0,134	40000	45000	0,0003	**K 3x5x7 TN**	-



Appropriate accessories

G seal	-
SD seal	-

Figure 20: K 3x5x7 TN needle bearing

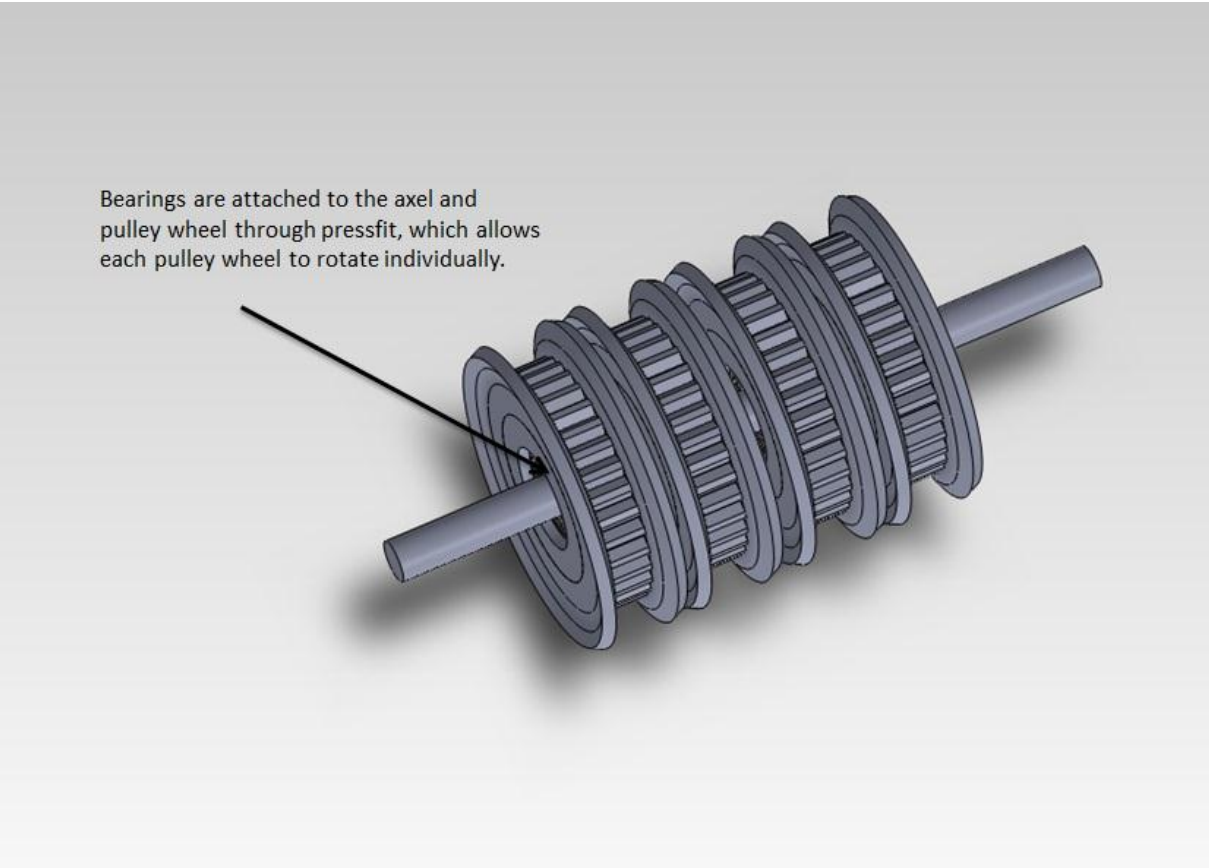


Figure 21: Illustration of lower pulley wheels

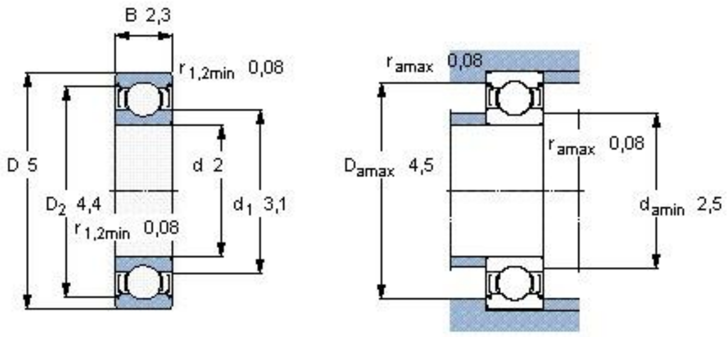
The roller bearing on the lower pulley is attached to the pulley wheel and axel through press fit. Roller bearings from SKF with data sheet[7] on Figure 22 is used.

Deep groove ball bearings, single row, stainless steel, shield on both sides

Product information

Tolerances , see also text
Radial internal clearance , see also text
Recommended fits
Shaft and housing tolerances

Principal dimensions			Basic load ratings		Fatigue load limit	Speed ratings		Mass	Designation
			dynamic	static		Reference speed	Limiting speed		
d	D	B	C	C_0	P_u				
mm			kN		kN	r/min		kg	-
2	5	2,3	0,156	0,048	0,002	190000	95000	0,00018	**W 638/2-2Z**

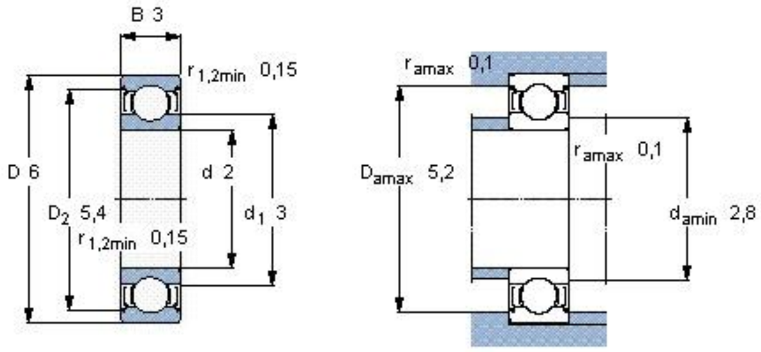


Calculation factors

k_r 0,015
f_0 11

Figure 22: Bearing

Principal dimensions			Basic load ratings		Fatigue load limit	Speed ratings		Mass	Designation
			dynamic	static		Reference speed	Limiting speed		
d	D	B	C	C_0	P_u				
mm			kN		kN	r/min		kg	-
2	6	3	0,238	0,075	0,0034	180000	90000	0,00035	**W 639/2-2Z**



Calculation factors

k_r 0,015
f_0 10

Figure 23: Bearing

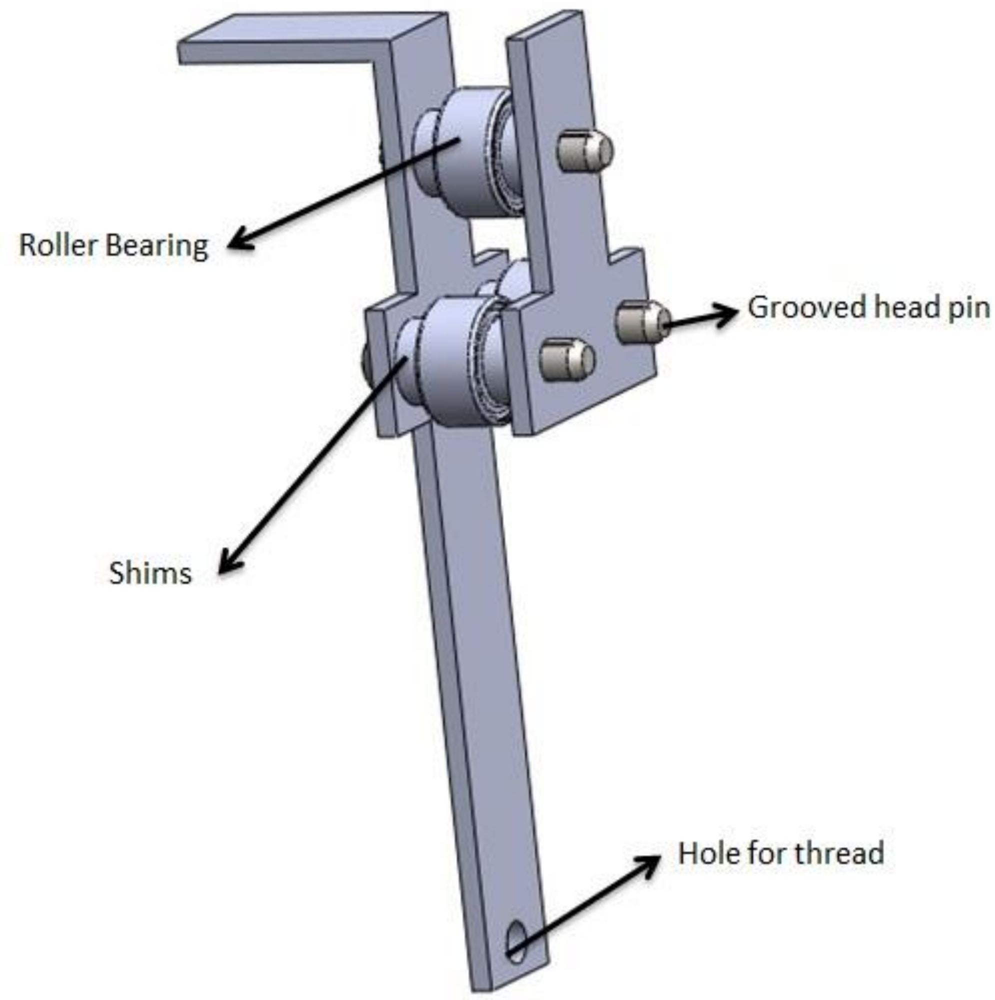


Figure 24: Arm

The arm is slightly changed for easier manufacturing, illustrated on Figure 24. The arm will now consist of two steel plates which are attached with round head groove pins, between the steel plates on the pin bolt it is attached a roller bearing with shims on each side of the roller bearings pressing on the inner ring of the bearing. The guide rail for the arm is machined with a track for the bearing. At the bottom of the arm there will be machine pressed a hole of Ø2mm for the thread. Data sheet[10] for the roller bearings on Figure 23.

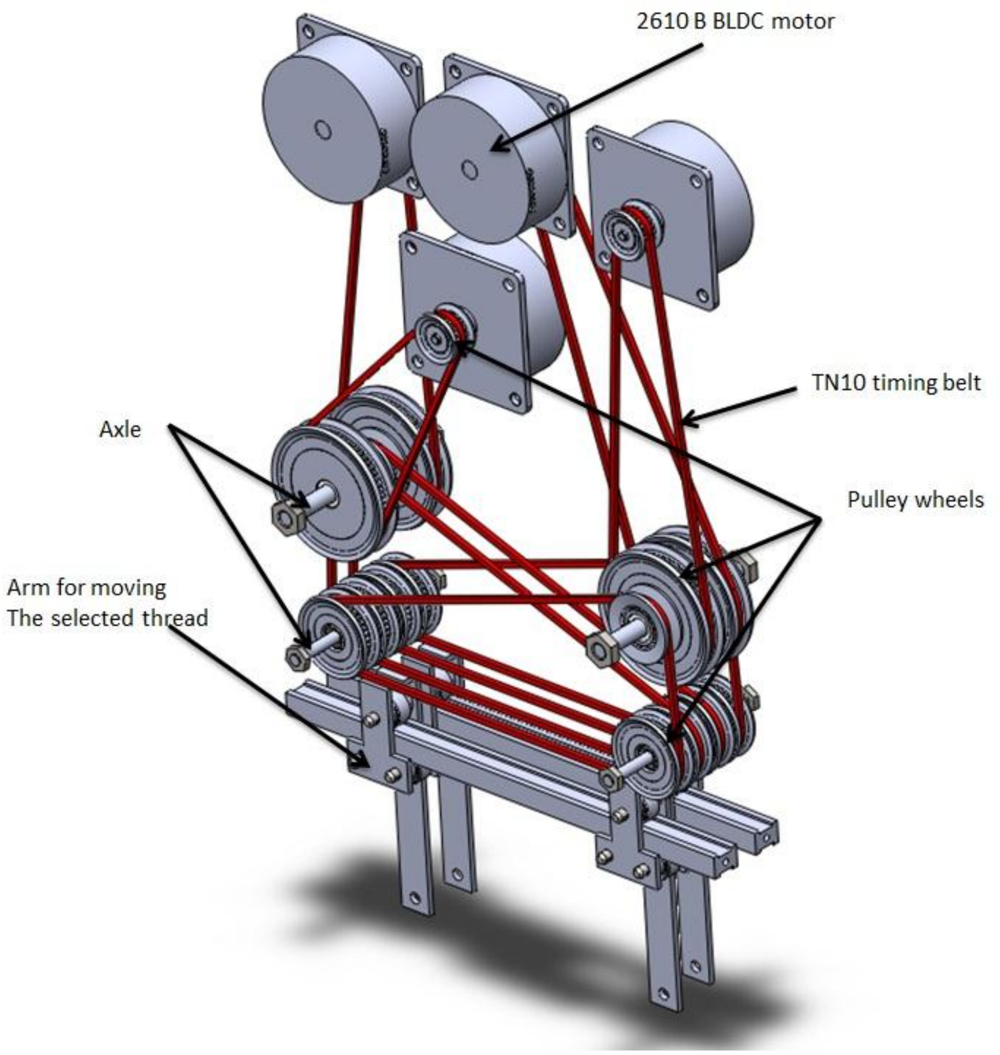


Figure 25: Discarded thread selection

Figure 25illustrates the discarded design. The idea is the same as before. The rotational direction of the motors will result in linear movement of the thread arms. The pulley wheels are specially made from the TN10 series, with double flange. Since the upper pulley wheels are mounted on the same axle, they are press fitted on a needle bearing. This results in rotational movement in both pulley wheels once one starts rotating. The TN10 timing belts have a width of 1mm and a pitch of 1mm. All bearings are from SKF.

From the discarded casing, the discarded casing consists of one sheet metal plate illustrated on Figure 26. The thickness was reduced to 1mm. The garage was where the gripper enters to pick up the selected thread. The upper pulley wheels have a diameter larger than the lower. It's therefore a hole for pulley the wheels to make clearance to the casing. The slide tracks are for adjustment of the axles.

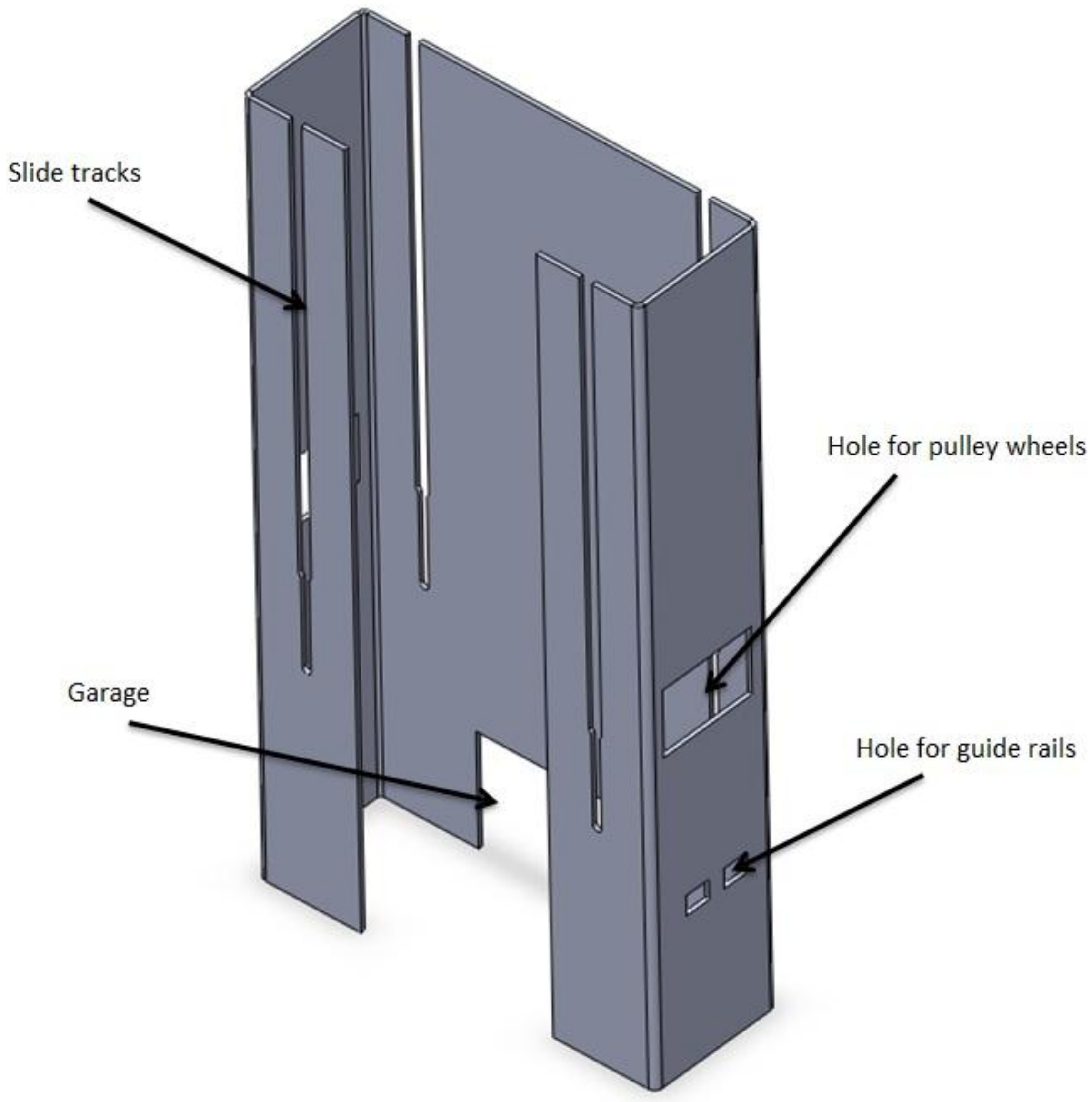


Figure 26: Discarded casing

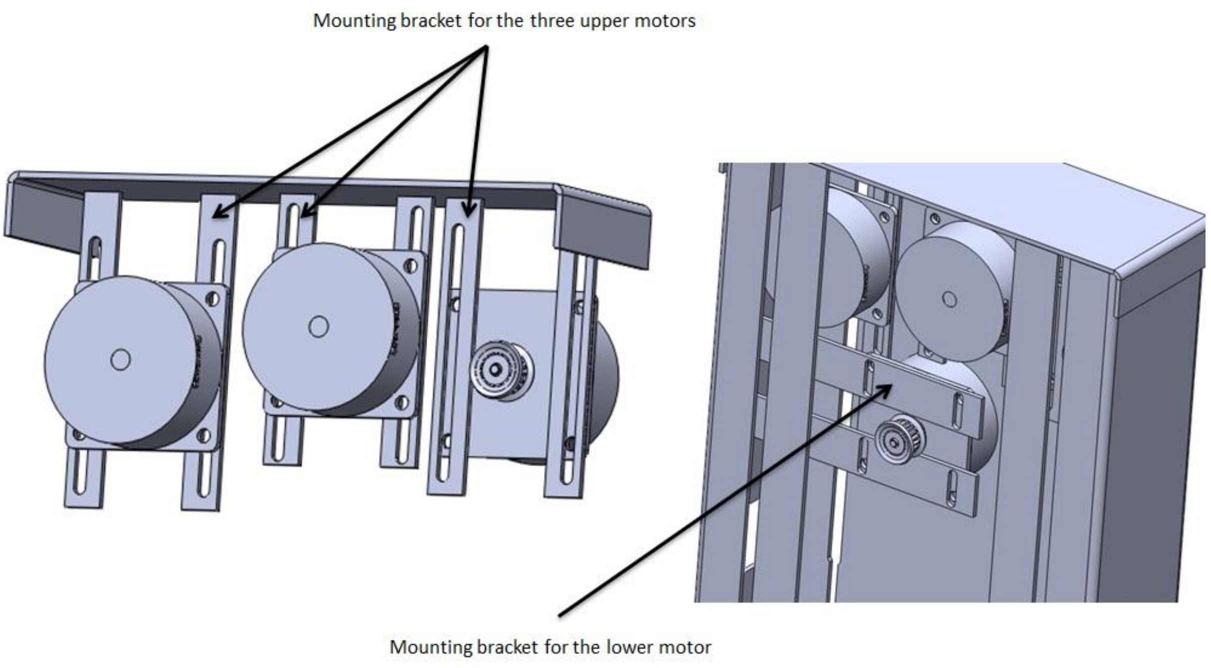


Figure 27: Mounting

Figure 27 illustrates the mounting bracket for the motors. The mounting brackets are changed from the discarded design, mainly because of production. The brackets will be machined pressed from sheet metal and buckled. The brackets consist of slide tracks for adjustment of the motors position and will be tighten with M2 bolts and nuts.

There will first be made a prototype for the thread selection system. This is because the current design is expensive and some of the parts, like the 1mm timing belts, have long delivery time. The prototype will mostly consist of standard components, and parts, that have short delivery time and a low price compared to the original design. The design for the prototype will not follow the space limitations given in "Total storage space" (D-00.A.10-EM). From the original design there are two modules. Each module contains four arms, a total of eight arms for eight threads. The prototype will consist of one module and two arms. We need one motor for each arm, so the prototype will need two motors instead of eight. One reason for making a prototype is that the price will greatly be reduced. Another reason to make a prototype is for testing whether our solution works.

Reason why this solution was discarded:

-Since the shafts only are supported on one side, the bearings will be subjected to a moment. This is not desirable.

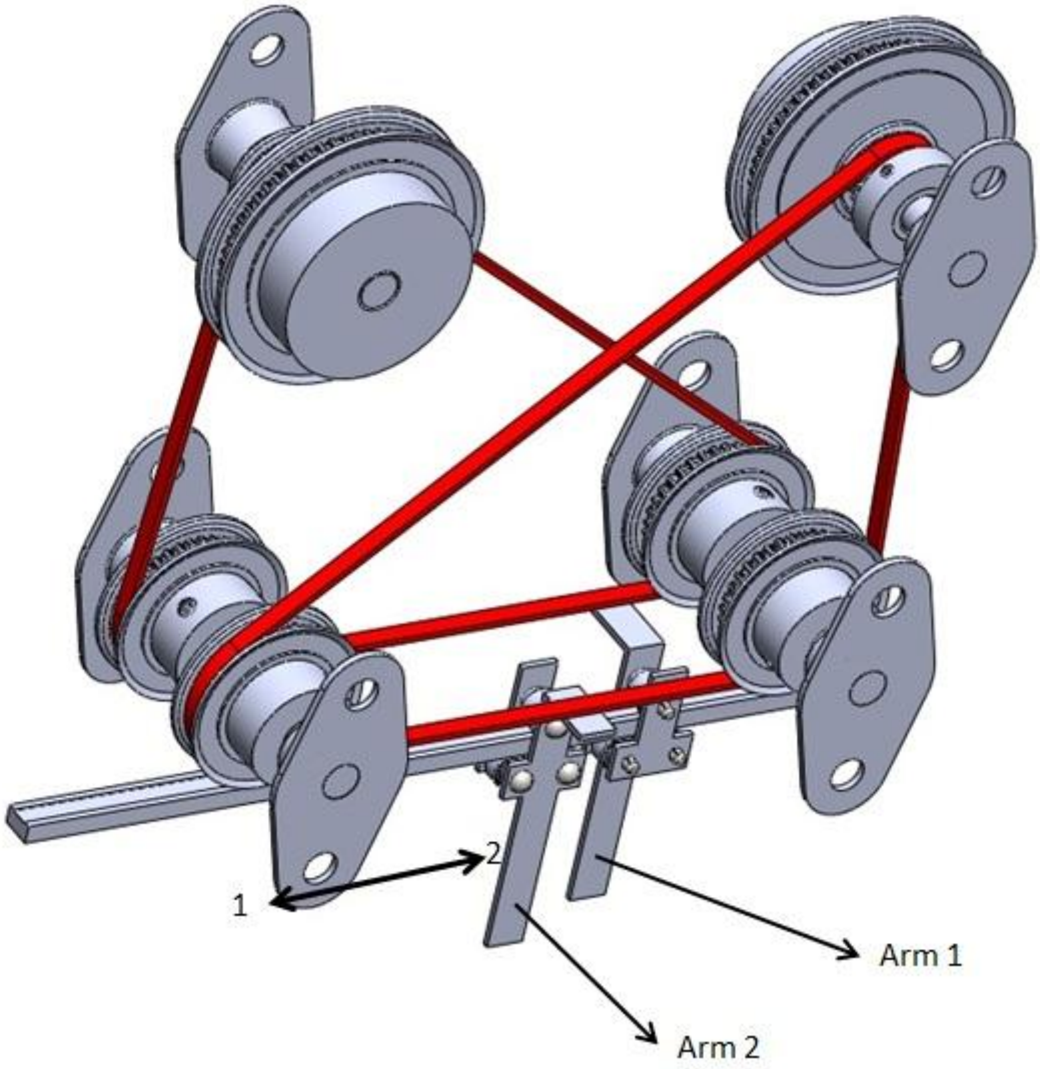


Figure 28: Whole system

Figure 28 shows the concept of the prototype. It is very similar to the current design with eight arms. The concept is the same. On Figure 28, Arm 2 is in the “ready for gripper position” where 1 and 2 on Figure 28 is the path for Arm 2. 1 is the initial position and 2 is the “ready for gripper position”.

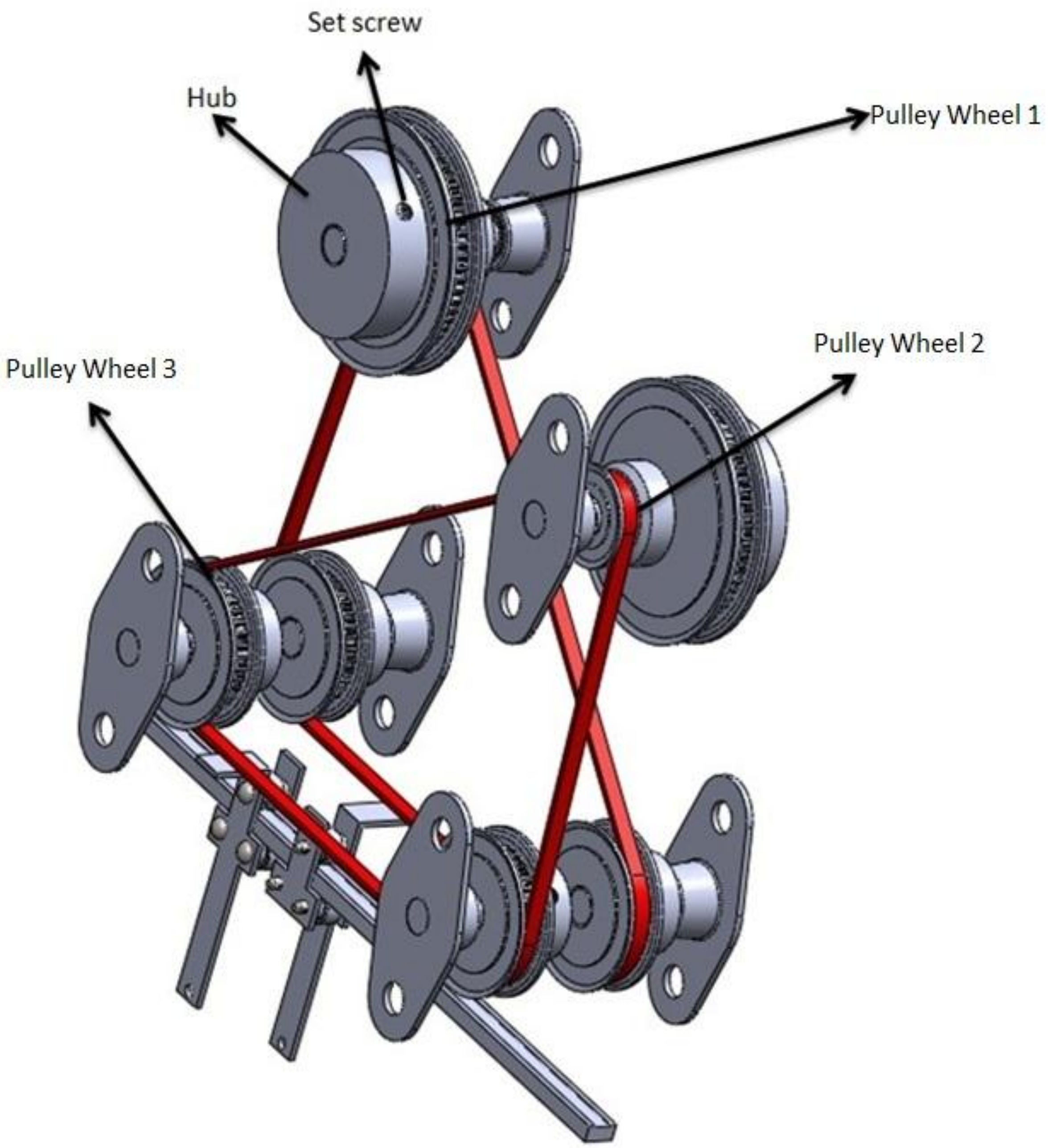


Figure 29: Whole system

Wheel 1 on Figure 29 is attached to a pulley wheel on the motor. The pulley wheel on the motor has 20 teeth, and the Pulley wheel 1 has 60. Wheel 1 and 2 is fastened with a set screw from the hub to the shaft. The shaft is inserted in a press bearing which is mounted to the casings tracks. This makes the press bearing adjustable to tighten the belts. All shafts will have free rotation, so when Pulley wheel 1 starts to rotate, wheel 2 will also start to rotate. Pulley wheel 2 will drive pulley wheel 3. The motor will be driving both ways. All pulleys are double flanged. This means that it is an edge on each side of the pulley to prevent the belt to slip off. All pulley wheels have a hub, shown in Figure 30. The hub contains a set screw which fastens the pulley wheel to the shaft. The reason why we chose pulley wheel with hub for the prototype is the price and delivery time. The other option was to use bearings on the shaft with press fit on the shaft and the pulley. This requires fine tolerances on the bore diameter on the pulley and on the diameter of the shaft. We still have the shaft which also is a press fit in the press bearing.

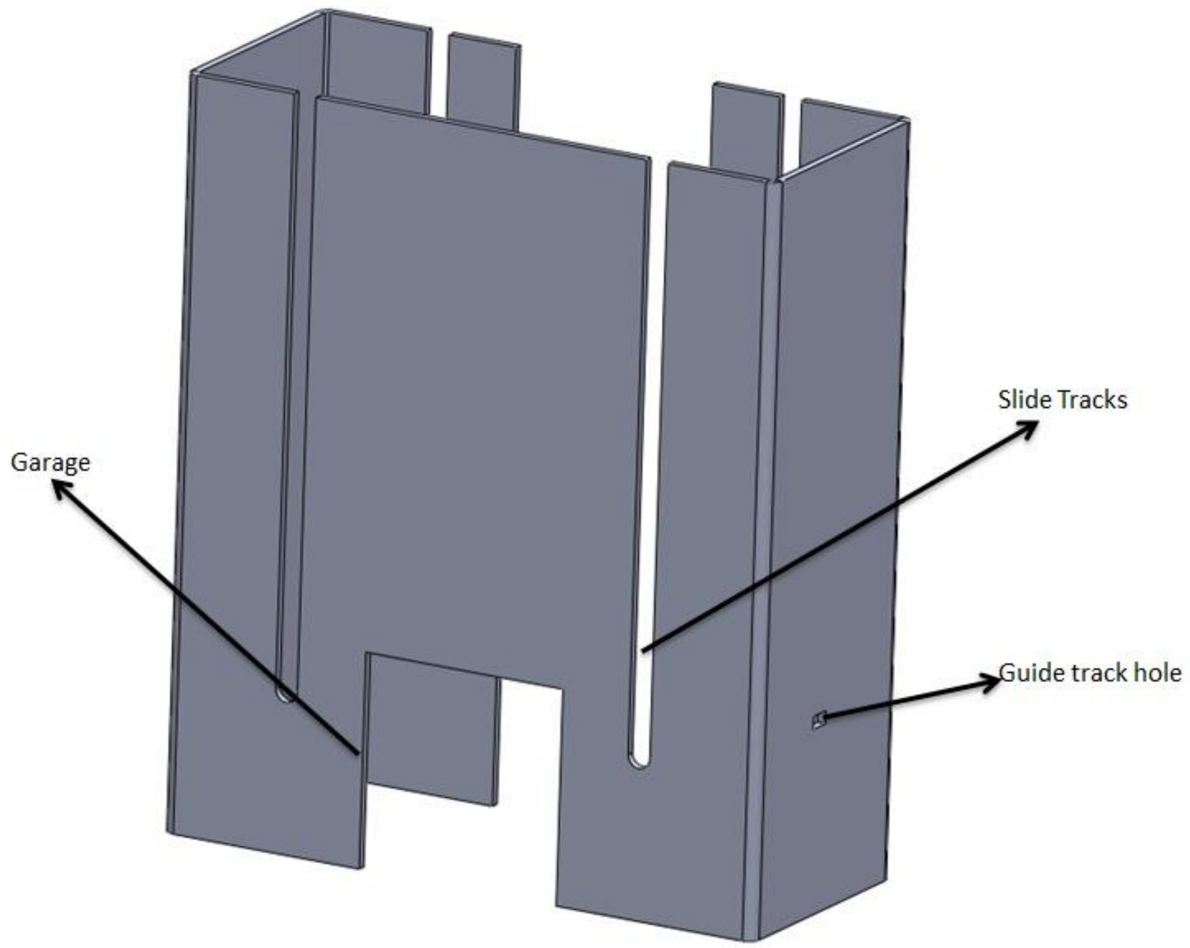


Figure 30: Casing

The prototype casing is also similar to the original design; –the main difference is the size. The prototype will therefore not fit on the TC2. The casing will contain the thread selection system and the thread holding and cutting mechanism. The garage is where the gripper enters to pick up the thread. The slide tracks are for adjusting the pulleys and the guide track hole is for the guide track. The slide tracks, garage and guide track hole is machine pressed and the casing is buckled.

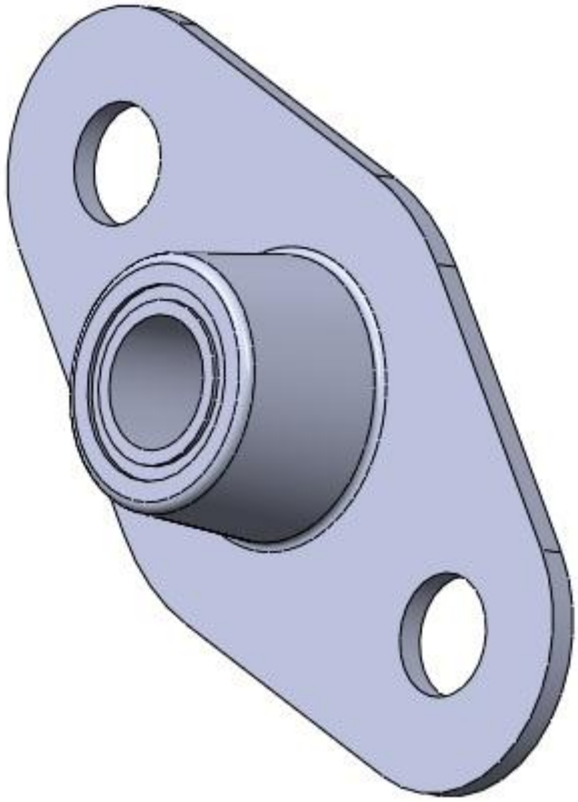


Figure 31: Press bearing

The press bearing, illustrated in Figure 31, is attached to the casing with two bolts. The position can be adjusted in the slide track of the casing. The bearing has a diameter of 6mm. The shaft will be inserted by press and this sets requirement for the diameter of the shaft. The diameter of the shaft has to be maximum 5,990mm and minimum 5,978mm. The tolerance of the shaft has to have a 0.4μm or finer finish.

The thread selection module is divided into 2 identical units. Each of these units contains four threads/arms.

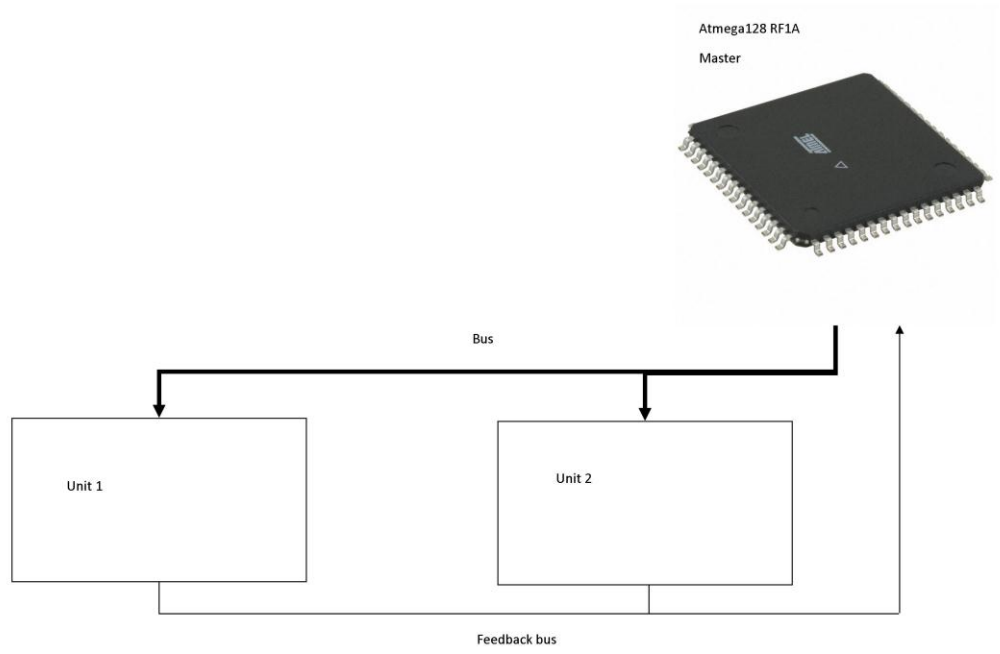


Figure 32: Communication set-up

As the Figure 32 above shows, the communication to the units will be done over a bus. The communication will be done by burst of bits. This means that each arm will have its own microcontroller, the selected microcontroller is Attiny861 [11]. This microcontroller has been selected for its functions and wishes from Tronrud Engineering.

As said, each unit will contain 4 arms and microcontrollers, like shown on the figure below.

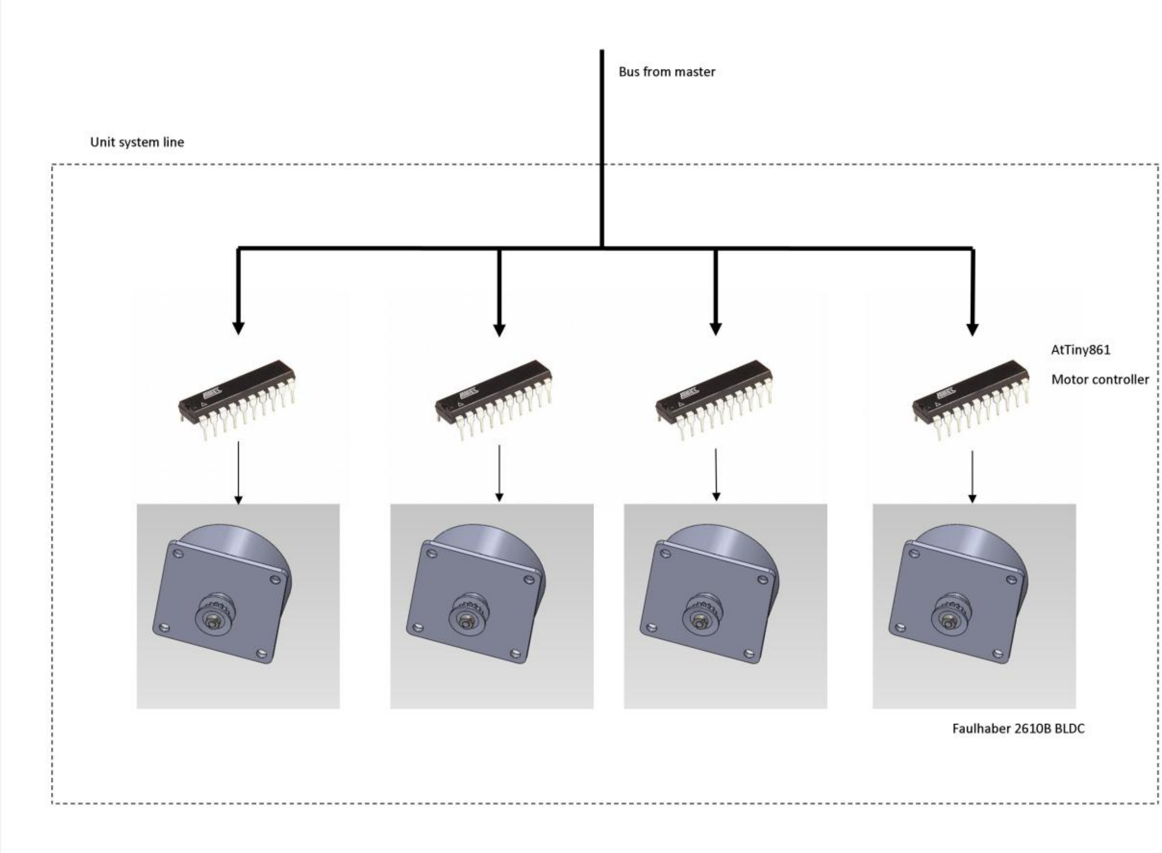


Figure 33: Unit set-up

As the Figure 33shows, each ATtiny will controll a Faulhaber 2610B motor. The Fauhaber motor is a small BLDC motor. This motor is chosen for its size and power, but the prize has been somewhat neglected when desigining. Each of the ATtiny microcontrolles will be connected to a MOSFET driving bridge; not directly to the motor.

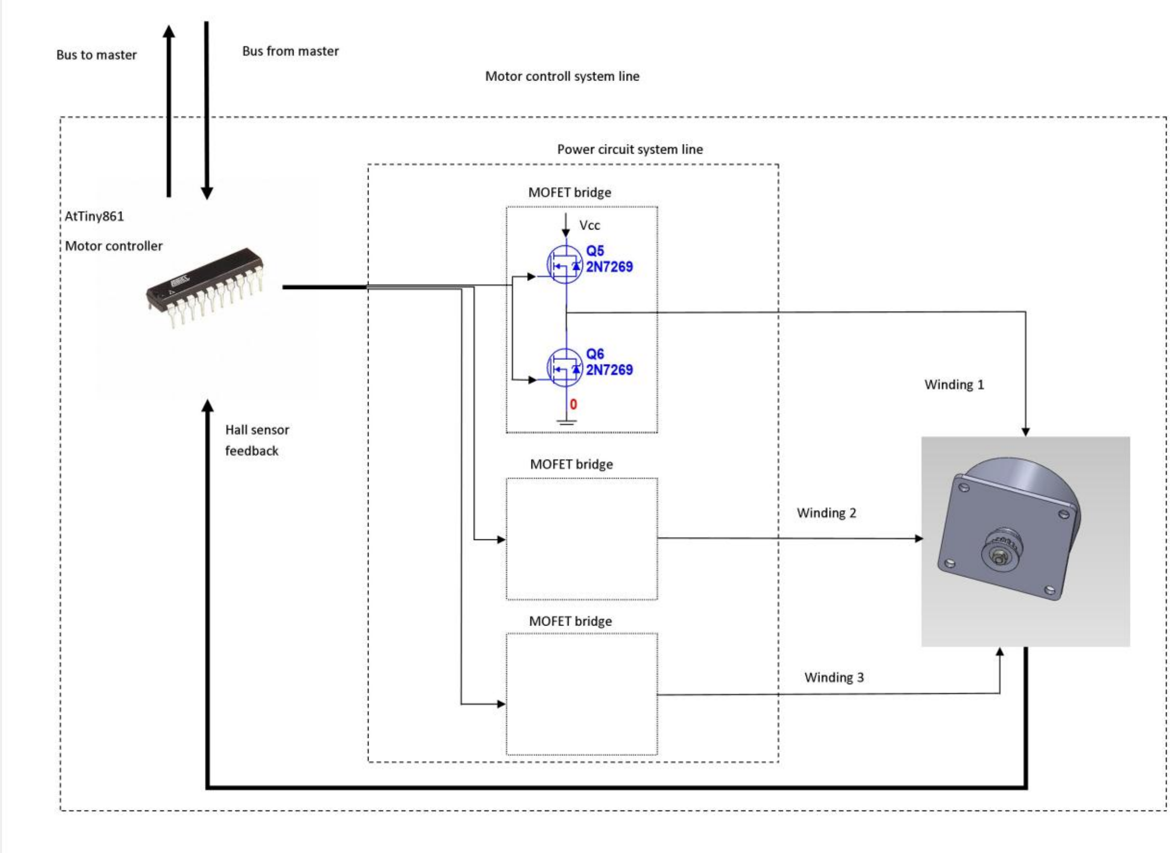


Figure 34: Arm set-up

The Figure 34shows the configuration of the controll circuits of each of the arms. The MOSFET bridge is for controlling the magnetic fields inside the motor to generate rotation.

ATTINY861

The ATtiny will be programmed as a position regulator. The regulator will controll the motor's accleration, speed and deceleration seen from where the arm is. When using a slave as a regulator, we minimize the needed interaction from the master microcontroller and therefore the master can handle other tasks while the selected slave drives the selected arm.

There will also be failsafes around the operation of the motor and arm, e.g if the arm "hangs", it will trigger a signal to the master controller to stop the gripper arm.

REGULATOR

The regulator will be a PI(D) regulator [12] with feedback control. This will let the microcontroller handle the acceleration and speed of the motor and then again the arm. This is relevant seen with the unknown forces that can appear in the arm due external forces. E.g., the tread "hangs" and therefore the arm needs more power to be able to pull it.

The programming for this regulator has begun, but is far from completed and will undergo many tests since precision and power are key words in this system. The program controls the MOSFET driver bridge via six PWM (pulse width modulation) channels, where each PWM goes to a MOSFET. This then changes the direction of the magnetic field in the motor that again drives the rotor.

COMMUNICATIONS

The communication between the slaves (ATtiny861) at the master (ATmega128RF1A) will be done by serial communication, i.e. burst of bits. The master will burst 6 bits to the bus that connects with the slaves.

The bursted bits can be seen from this table:

Table 1: Communication addressing

Address of arm bits	Direction bit	Verification bit
0001->1000	1 or 0	1 or 0

Address bits will go from 1 to 8, giving each arm a unique address. The direction bit will then tell which way the arm should move, 0 for out and 1 for in. This is implemented in case of error, and to gain better controll over the arms from the master. There will be software restrictions so the arm will not move past its end points even if commanded to. Verification bit is then used in case of disturbance in the system, so the number of 1 in the bursted bit shall be an even number. If the recived bit burst doesn’t have an even number of 1's, the command will be rejected and the master asked for new command. The ATtiny will give a signal for recived and completed tasks through the feedback bus.

REASONS FOR DISCARDING THIS CONTROLL AND MOTOR DESIGN

The reasons why this control idea was discarded was mainly:

- Time consuming design
- Cost

As the research for the design was done, the problem with the complicated circuits appeared. To hold the cost of this project down, the idea was to design the whole circuit for scratch. So the challenge was how to ensure that the motor got enough current to run properly. To run a N-Mosfet at full capacity, the gate voltage has to be higher than the needed voltage for the motor. This required a fast dc-dc conversion that can be done with using a “line driver” (cost approx. 100,- NOK per unit). We would need 3*8=24 “line drivers” for the whole thread selection module. Seeing that we also would need Mosfet's, operational amplifiers (set up as a hysteresis for sensing over usage of current) and other smaller components like resistors and capacitors.

This would have resulted in a complicated circuit that would probably require a lot of testing and bug finding, and this we didn’t have time for.

MODULE 22: THREAD FEEDING SYSTEM

MECHANICAL SOLUTION

We have been discussing the option to have a dynamic buffer. This buffer would pull thread of the spool while the gripper is not pulling the thread. This dynamic buffer would reduce the threads let-off acceleration from the spools so it would not start to self-spin. This kind of buffer would also make the thread very loose and easy for the gripper to lay a pick.
This solution was discarded because it seems to be unnecessary complicated, and it's difficult to store 1-2 meter with loose thread without problems.

MECHANICAL SOLUTION

ALL SPOOLS VERTICALY SIDE-BY-SIDE

Having all the eight spools side-by-side was one of the first solution we were thinking of. The benefit with this solution is that we will have plenty with space above the spools, but it will be problematic to get enough space in the width. We have therefore discarded this idea.

TWO ROWS OF VERTICAL SPOOLS, WITH THREAD TRAY IN THE MIDDLE

We have discussed the possibility to have four spools in the lower row and four spools in the higher row, with a common thread tray in the middle. The benefit with this solution is that it's space efficient, but some of the spools will need to be hanging upside down. This can be done with locking the spools to the frame with for example inserts. This is especially a problem for the conical spools because it will most probably continue to spin out thread because of the gravity, and has therefore been discarded. Figure 35shows an illustration of this solution proposal.

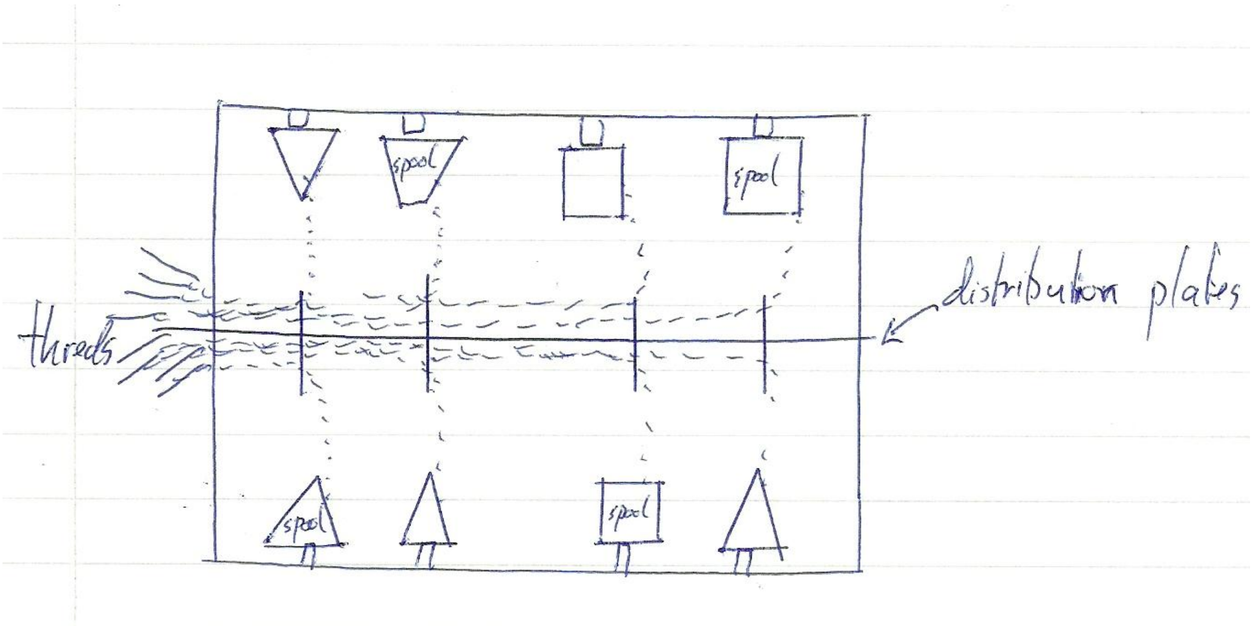


Figure 35: Two rows of spools and tray in the middle

Setting the spools above each other makes the module higher than the dimensions set. This could be fixed with placing the spools offset to the tray. Figure 36 shows how we can mount the spools in an offset from the thread tray. The problem with height is fixed, but the we get problems with depths, which we think is more difficult to achieve because space for the beater. This solution is therefore discarded.

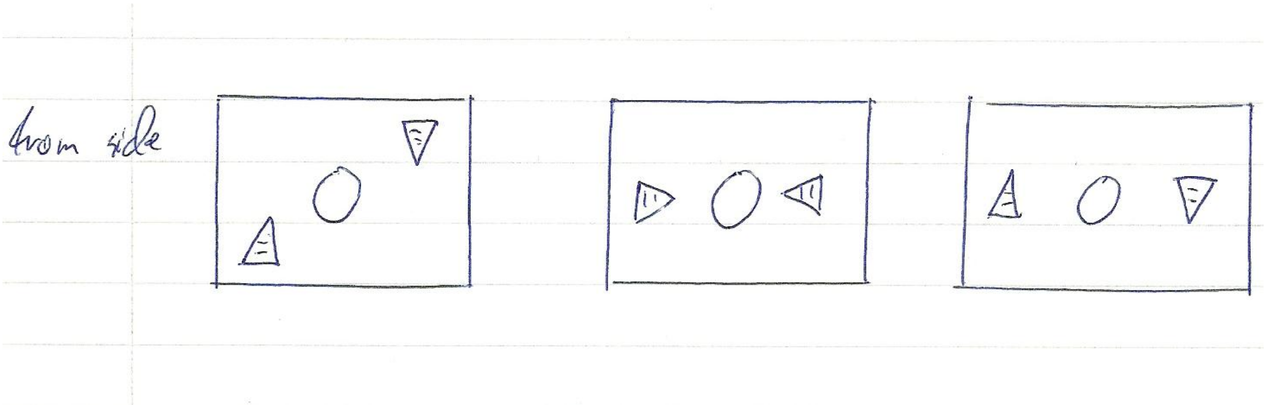


Figure 36: Spools offset

We have been working with a solution to fix the problem that the spools are too high or too wide. A solution we found for that was to have three rows of vertical spools. That would give two rows with 3 columns and one row with 2 columns. The empty "space" would be the place where we fasten our microcontroller. We haven't discarded this idea, but it will be much more complicated to build, so we prefer the solution with vertical spools instead. Figure 37 shows how much space is left for other components or modules.

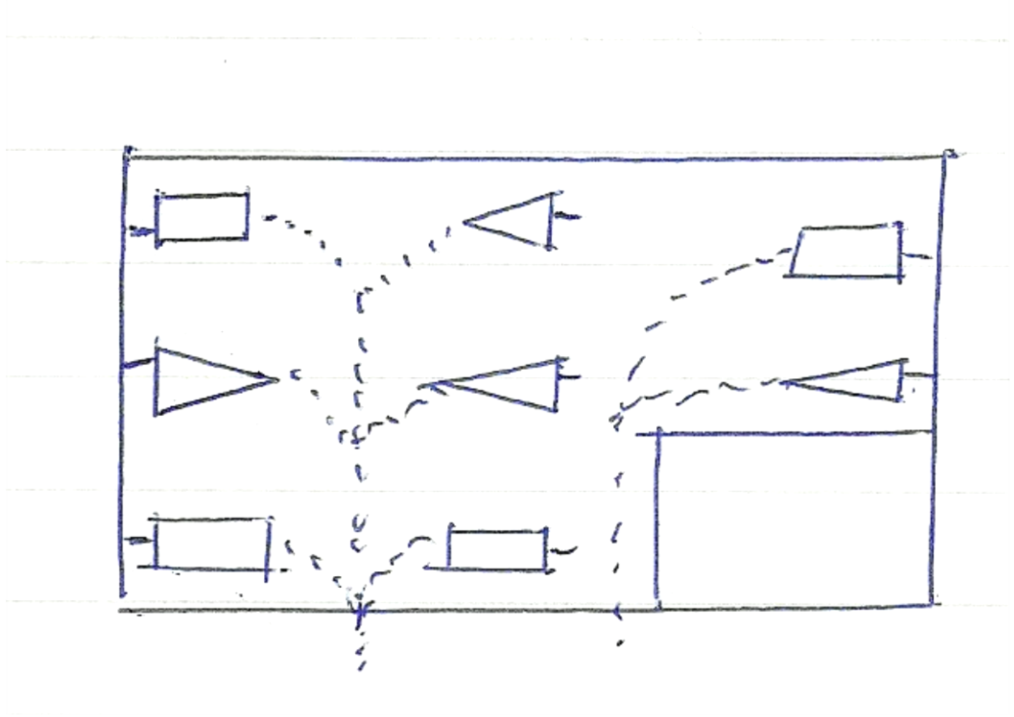


Figure 37: Three horizontal rows

This is the first draft of the solution we were going for at an early point, which has two thread trays. This first solution consists of two rows with vertical spools, and a single thread tray above. Figure 38 illustrates how the spool holding system was thought. It consisted of fixed spools and beams that the thread was going through, centralizes the threads. Figure 39 shows a CAD-drawing of the first draft. This solution was edited because we discarded the idea of pulling thread directly from the spools and that the system would be too expensive. The solution, in we are going for is described in the document “Design and analysis D-00.A.18-EM”.

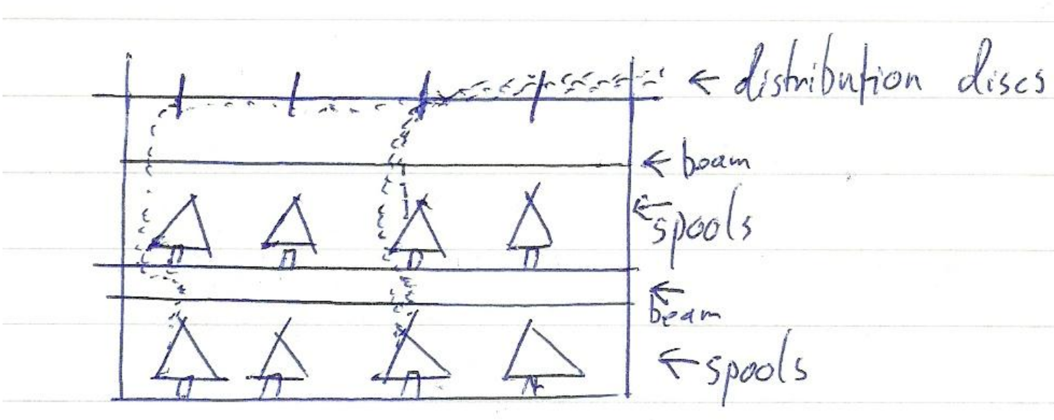


Figure 38: Thread tray at top

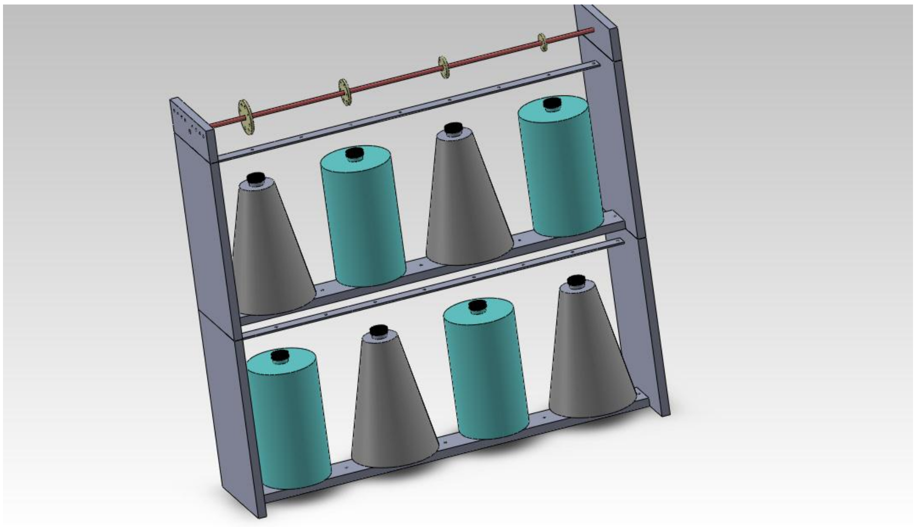


Figure 39: CAD-drawing

In the beginning we were thinking of having spools that were rotating, especially those that was not cone shaped. This was to make the system equal for every type of spool. The problem with a rotating spool is that it has a bit moment of inertia which will cause the spool to continue the spinning after the system has stopped pulling the thread.

We have thought of a solution that could let the cylindrical spools spin, and the cone be fastened with some sort of inserts that could be locked or let open. We have now a hypothesis that we do not need to spin either the conical or cylindrical spools. If that's correct, it will be a lot easier to avoid trouble with the threads. We are a bit concerned about not rotating the cylindrical spools, making it difficult to extract the thread from the spool. We have therefore thought of a 45º upwards let-off angle for the thread from the spool. The thread must go through a centered eye above the spool, so that the thread does not get a circular motion off the spools. This is shown in Figure 40. If it turns out that the threads gets a circular let-off motion, it can be avoided the mounting a funnel above the spool.

Of course, if there is a problem with extracting thread from the cylindrical spools, we can make a solution using only standardized cone spools, a plan B (which we later were going for). This however, clash with the requirements set. The use of different size spools requires different liners or fastening discs to keep the spools in center.

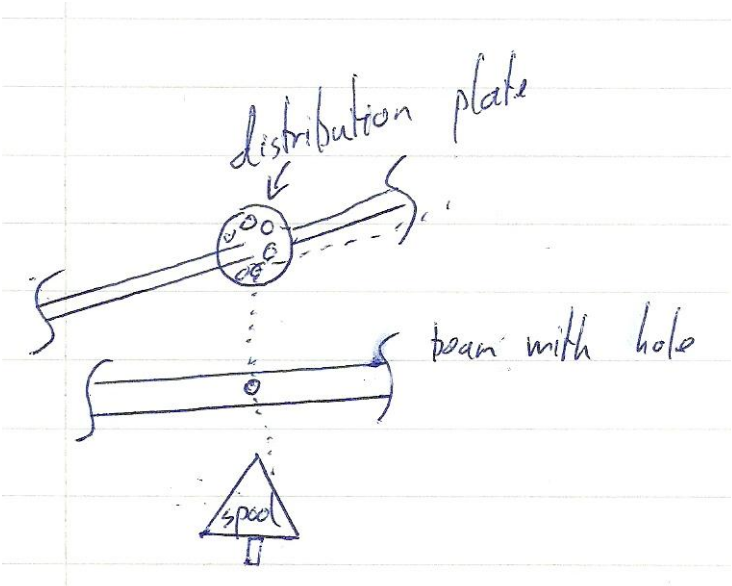


Figure 40: Beam with centered hole above spool

Because of friction along the cylindrical spools, we have a solution with a rotating arm. Figure 41 shows how we thought of a rotating arm the first time. The arm will rotate after where the thread is pulled from the spool. This arm makes the thread let-off angle large, and centered by the spools middle. The problem is that we only moved the problem. The rotating arm will have some moment of inertia which will result in that the arm will keep spinning a bit after the thread is no longer pulled off the spool.

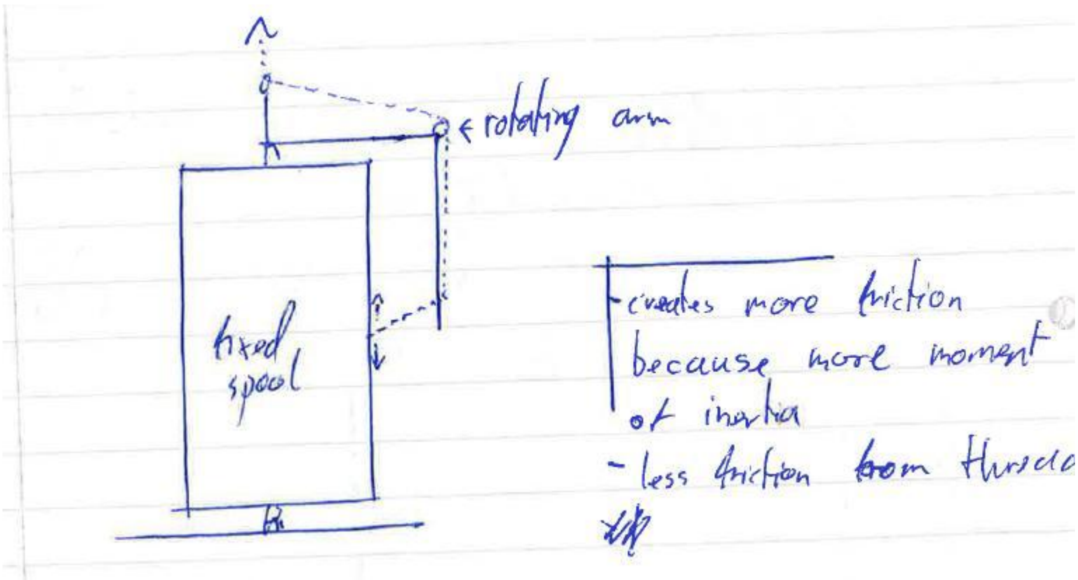


Figure 41: Fixed spool with rotating arm

The best thing to do is to eliminate rotation in the spool holding system completely. The solution consists of just a disc fixed to the spool pin. Figure 42 shows how we think the disc will be placed. The disc needs to be just a bit wider than the spools, or else the friction will just increase. The eye above the disc, as shown in Figure 42, will be moved to the thread tray itself. This in turn, makes the spool holding system lower and number required of parts will decrease. There is one problem though: tests show that the force needed to pull off the thread of the spool gets larger if the disc is too large. This can be a problem when the spool is getting smaller in diameter when the spool is becoming empty for thread. We have therefore discarded this idea, and developed the solution with a rotating arm.

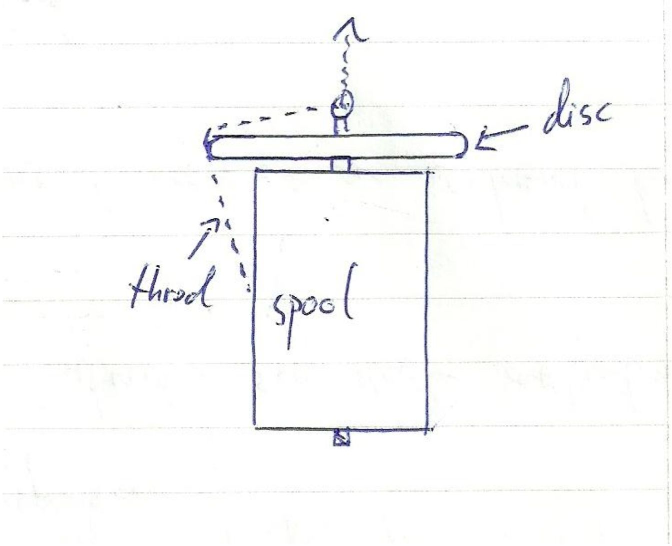


Figure 42: Spool with disc above

As it turns out, tests with cylindrical spools shows that pulling off thread straight from the spool is difficult without using too much force. This resistance occurs because of friction along the side of the spool. We want to keep the system with fixed spools, but need to redesign. We thought of a rotating arm on top of the spool. This would make a positive let-off angle for the thread, drastically decreasing friction along the side of the spool. It is however important that the rotating arm has very little friction or rotating resistance. The rotating arm must of course not stand in the way for locking the spools to the frame. But it's always a tradeoff on rotary friction and stop time for the arm (more friction, shorter stop time and vice versa).

Figure 43 shows an early version of the rotating arm system. The let-off angle will be changing when pulling thread off the spool, but will always remain positive. Figure 44 shows a CAD drawing of a spool pin with rotating arm. The rotating arm and center pin is supported by two roller bearings.

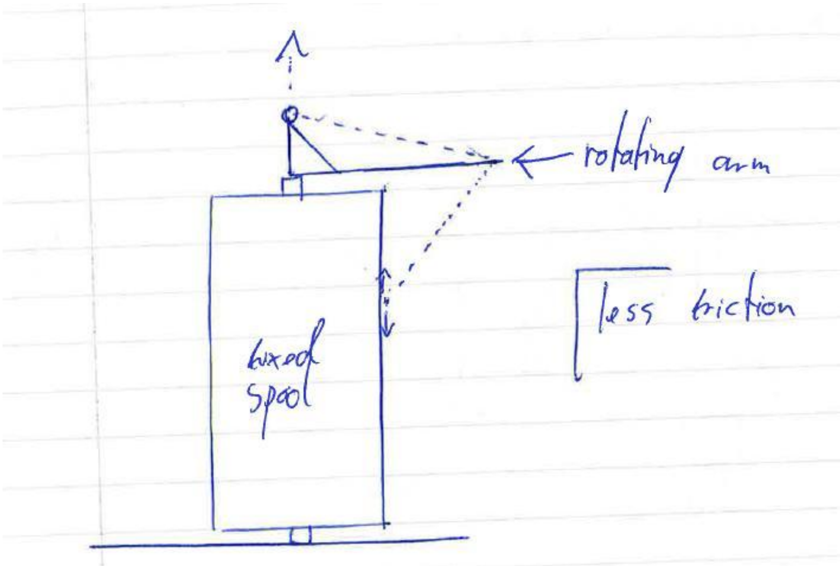


Figure 43: Spool with rotating arm

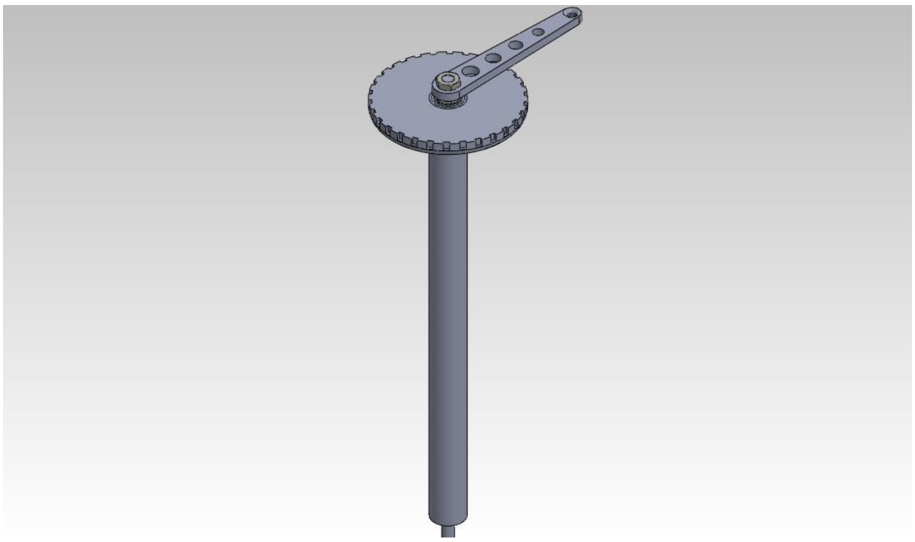


Figure 44: Spool pin assembly

It turns out that the rotating arm generates too much moment of inertia, and this makes the thread continues to spin out after being spun out at high speed. We have thought of different solutions to avoid the unwanted rotation in the spool holding system (you can read more about these solution in the document "Test report D-03.A.20-A"), but have concluded that this rotating arm was the only solution that actually did not have any problems with the friction. We have therefore decided to go for the rotating arm, but we need to do some modifications on it. The arm has to stop rotating as soon as the gripper is no longer pulling thread. The solution we have found for that is to connect the rotating arm with a drive axle inside the center pin. At the bottom of this drive axle we will be mounting a sort of braking mechanism that will receive signals from the yarn sensor, through the microcontroller. We have thought of mounting the brake at the top of the spool, but this will require electrical wiring for the user to take care of when changing spool. When the gripper is no longer pulling the thread, the yarn sensor will give a zero-output, and that will trigger the braking mechanism. This solution was discarded by Tronrud Engineering because it would be too expensive and complicated prototype wise.

THREAD TRAY

We have agreed on using a thread tray to distribute the threads from the spools to the thread feeding system. This first system consists of a beam with distribution plates. We are thinking of using different distribution plate sizes, which reduces material and saves space. One problem we come up on was that cylindrical spools require a larger distribution plate than cone spools because of a required larger and positive let-off angle. Figure 45 shows this problem when the spools are rotating. We later discarded this idea and decided for a solution where the spools are fixed and the threads are led through an eye before they are led to the tray. This is described in the chapter above.

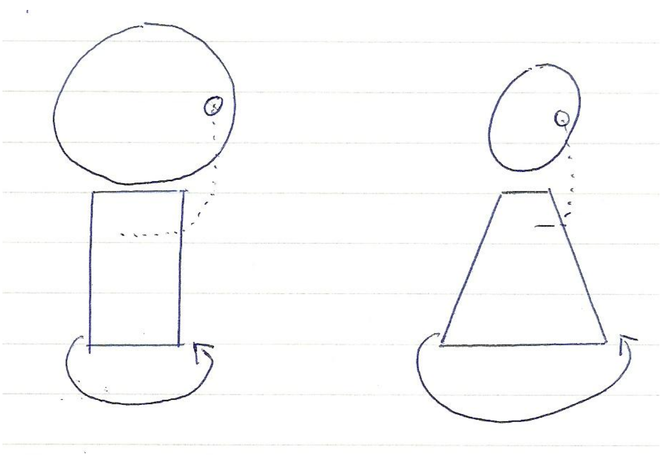


Figure 45: Distribution plate sizes

It can also be mentioned that we also considered beams that the treads go around. This would make the let-off angle larger, and make a possibility for reducing the distribution plate size. This proposal consists of rotating spools, and is shown in Figure 46.

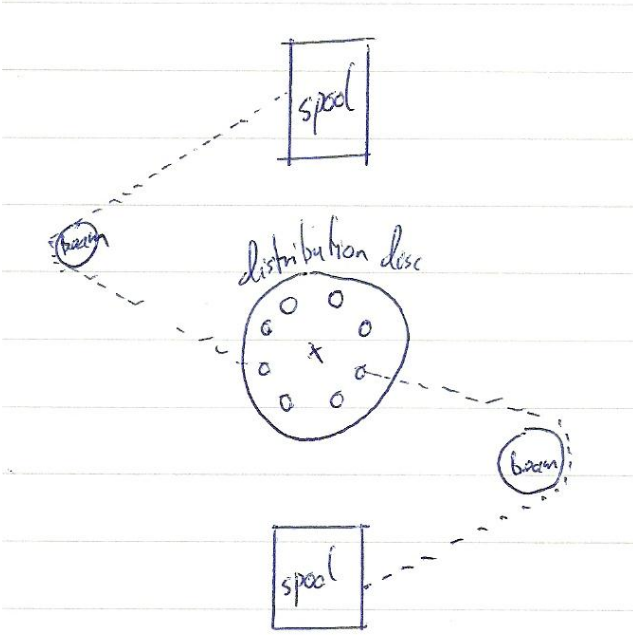


Figure 46: Let-off beams

We were thinking about using distribution wheels mounted to a rod as thread tray with C-clips. A CAD drawing of this design can be seen in Figure 47. This solution was later discarded because its wheels were thought to be too expensive for prototype testing. We have therefore chosen to make the thread tray out of sheet metal (as can be read about in “Design and analysis D-00.A.18-EM”).

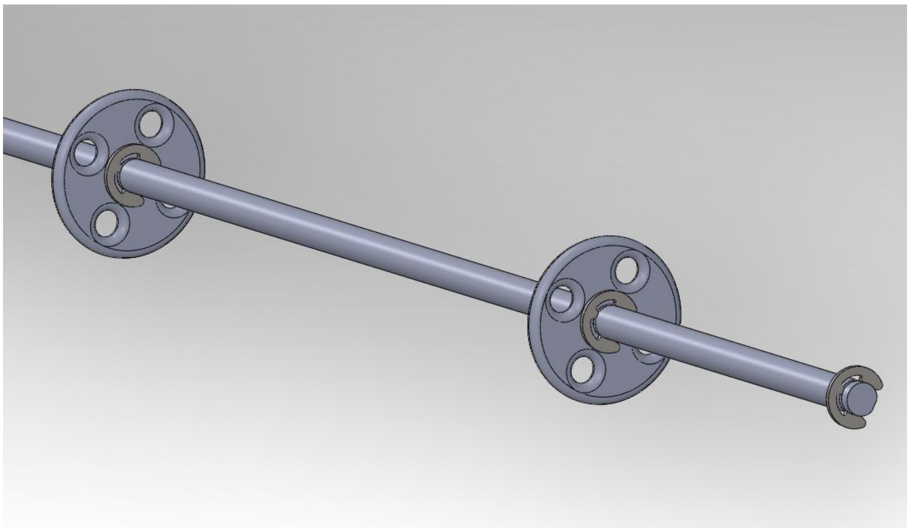


Figure 47: Thread tray with wheels

Instead of sheet metal, we could just use a M5 threaded rod with hooks welded to some nuts. This is maybe a too simple solution, and this is why it was discarded. Figure 48 shows a sketch of this solution.

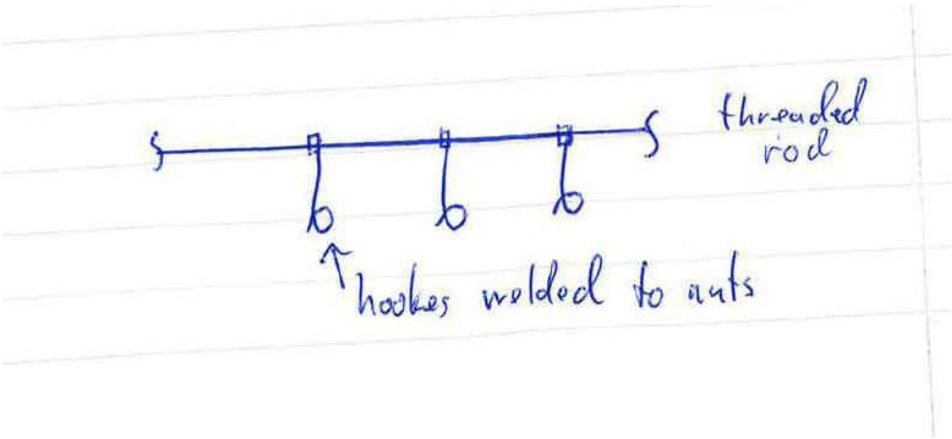


Figure 48: Rod with hooks

Tronrud Engineering also came up with an idea using sheet metal. Figure 49 shows this solution. It consists of buckled sheet metal. A distribution plate is stamped out and need to consist of guides to make sure that the edges do not cut the threads. This idea was discarded by us because we thought we could design an even simple solution. It would also be a little higher.

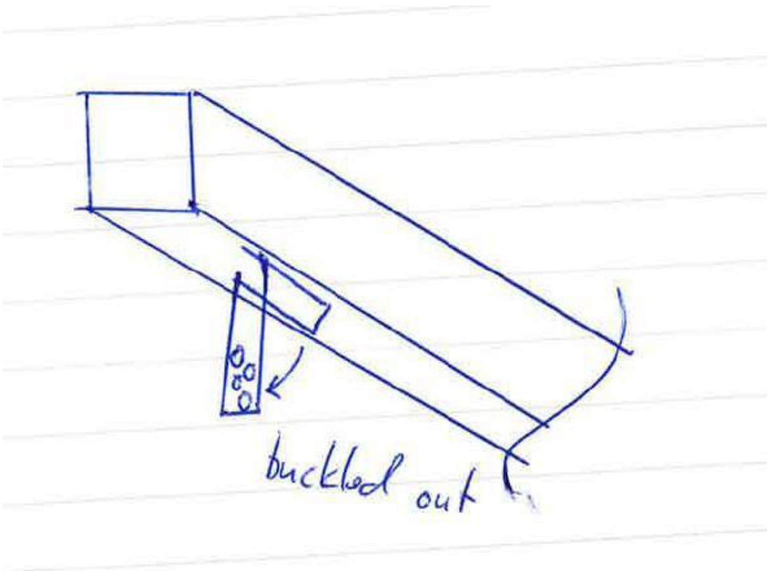


Figure 49: Sheet metal buckled out

MICRO SWITCH

We have looked at a solution to have a micro switch-sensor, as seen in Figure 50[13], which will give an output if the thread pushes the button down. This solution could work if the thread was in tension, but until now we are planning a solution where the thread is not in tension before the thread selection system, so it might be difficult to have the button pushed down in the time while the thread is not moving. The benefit with this solution is that it's quite cheap.

Figure 50: Micro switch

UPG

This sensor[14], illustrated in Figure 51 were suggested by the company Eltex of Sweden as a sensor we could try to use. We got the offer to try this for free, but since we would need eight of this sensor, we found that it would be cheaper to have an 8-hole built in sensor. We then went for the G3W sensor, which most probably will work according to the company.

Figure 51: UPG thread sensor

ELECTROMAGNETIC BRAKE/CLUTCH

Figure 53: Brake/clutch

The Rotating-arm solution made it necessary to have a braking-solution because the moment of inertia on the rotating arm made it continue spinning even after the thread no longer were pulled of the spool. We therefore were investigating the possibilities to use a brake on this arm; an example of a brake is illustrated in Figure 53. This solution would cost NOK 3200,-. Therefore the requirement that we has to use cylindrical spools where degraded to a B-requirement that we will look at later. In the beginning we will only use cone spools. With this solution, we do not need any arm, and therefore no brakes.

We did also look at alternative and cheaper ways to stop the rotating arm from spinning, for example with the use of a solenoid that presses on the rotating center axle. The Figure 52 to the right illustrates this.

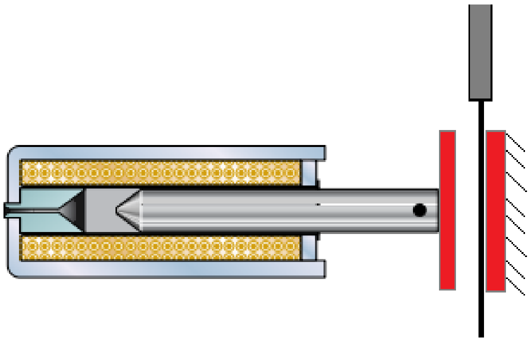


Figure 52: Solenoid + Brake

MODULE 30: CONTROL

DAC INSTEAD OF ANALOG COMPARATOR

PLAN B

If we of any reason fail to use the analog comparator to identify how many threads are moving, we can use analog-to-digital converter (DAC) instead. The use of a DAC will reduce the number of components, and also use Port F instead of Port E which we have proved to be a bit buggy. The disadvantage with the DAC is that it does not have the ability to trigger an interrupt flag, which we would like to reduce the calculation costs while checking for two threads while the gripper is in the thread selection system.

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MODULE BUILDING FOR THE”AUTOMATIC SHUTTLE CONTROL SYSTEM”

D-00.A.33-EM

Release 1.0

RELEASE NOTES

Date	Version	Description	Author
14.05.2012	0.1	Created document for module building	Andreas Stustad
21.05.2012	0.2	Added building of module 23 and 00 Grammar and spelling	Andreas Stustad
23.05.2012	0.3	Added intro Added building of module 22	Andreas Stustad
29.05.2012	0.3.1	Added module 20 and 21	Andreas Vander
29.05.2012	0.3.2	Added module 10,11 and 12	Vazgen Karlsen
29.05.2012	1.0	Finalized document	Andreas Stustad

ABOUT THIS DOCUMENT

This document will mostly show pictures and explanation under the building and modifying of the modules in the 2nd construction iteration.

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INTRODUCTION

This document will document the building and modifying of our prototype module. It consists mostly of pictures from the building phase with some explanation. The chapters are divided into module numbers.

Figure 1 shows a picture of the prototype module nearly assembled. Arrows point to the different modules on the prototype, and they have a description to understand which module it actually is. This gives an overview of the prototype.

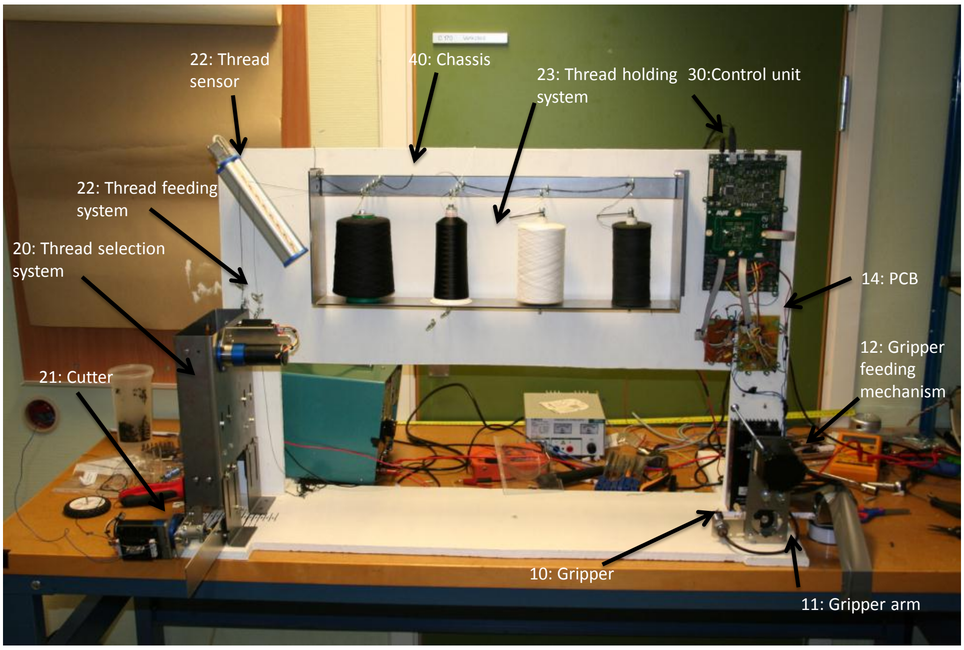

Figure 1: Module overview

The entire system consists of every other module that is bolted to or has interconnection to the chassis and is working as a system. The main modules are the thread/spool holding system, the thread selection system and the gripper arm feeding mechanism.

Figure 2 shows the system partly assembled. The thread/spool holding system and the thread sensor is mounted to the chassis, but the thread selection system is only placed on the chassis.

Figure 2: System partly assembled

Figure 3 shows the system more assembled than above, with the electrical circuit cards mounted and the gripper arm feeding mechanism almost finished.

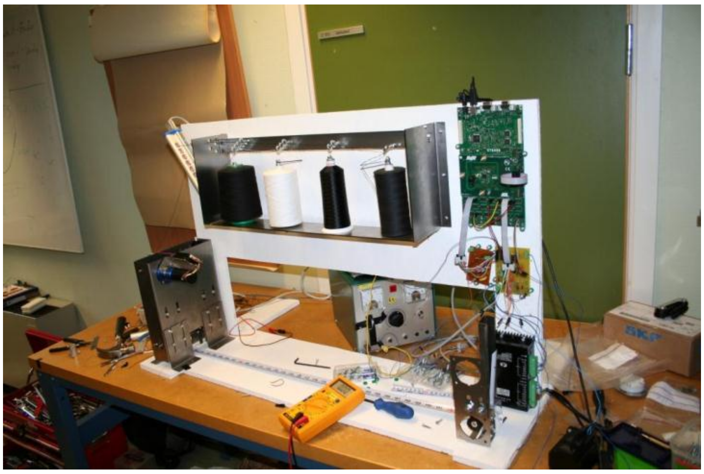

Figure 3: System

Gripper consits of three simple parts, two plastic parts that are curved with the same shape as the gripper arm (measuring tape) and a simple hook made of sheet metal. Parts of the gripper are shown below in Figure 4.

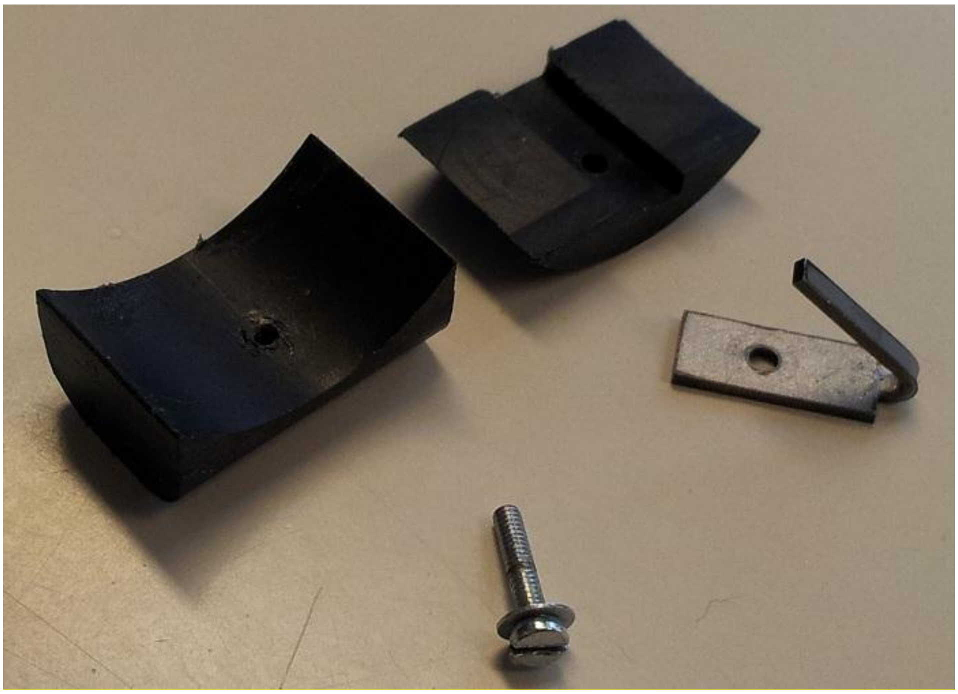

Figure 4: Gripper parts.

Gripper is assambled and mounted on gripper arm below in Figure 5.

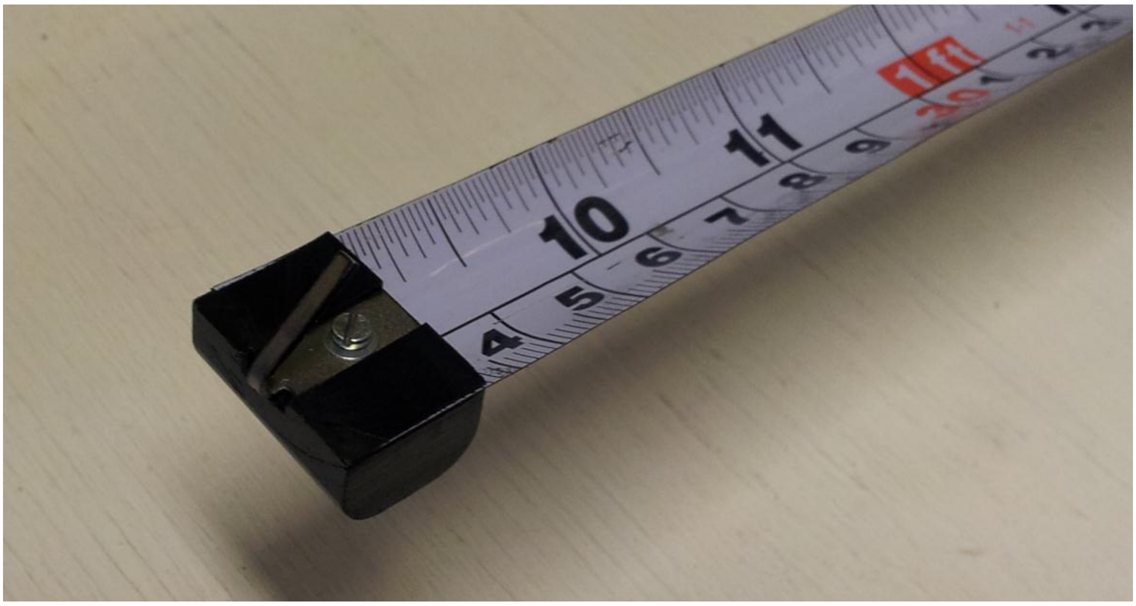

Figure 5: Gripper mounted on the gripper arm.

Feeding mechanism consists of several wheels and a frame that holds the whole assembly together. Test of the feeding mechanism resulted in sideway instability of the gripper arm. Therefore we made some guiding parts that were installed on existing prototype model to support sideways movement. Feeding mechanism and guiding parts are shown below in Figure 6.

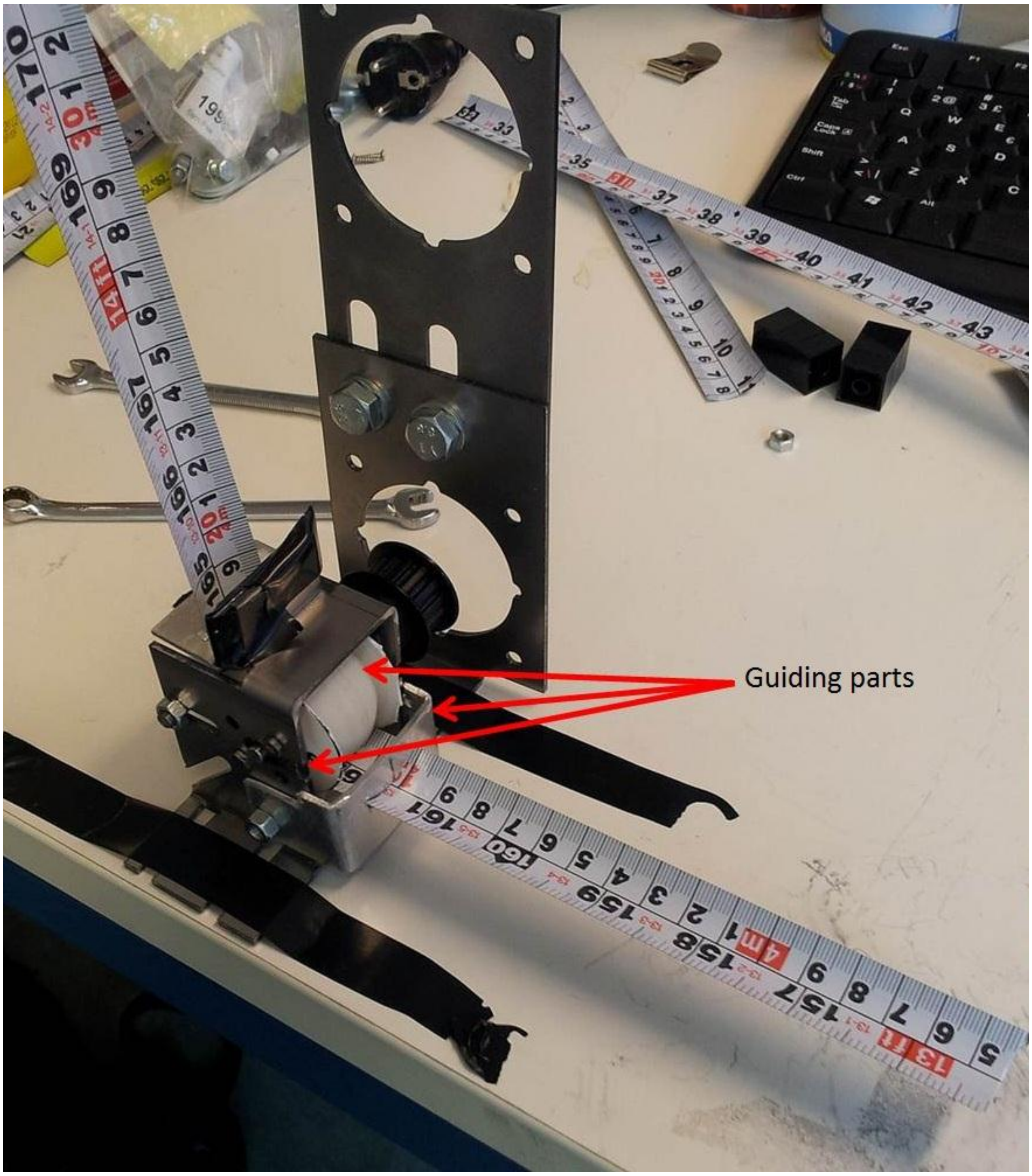

Figure 6: Assembled feeding mechanism with guiding parts.

Feeding mechanism with guiding parts was better, but not stable enough. Guiding parts were not tough enough and over time the whole movement of the gripper arm became unstable. Guiding parts were replaced with new parts with higher material durability, but it resulted in damaged gripper arm because of the abrasion.

We got some tips about this problem from an employee at VN Link who works with conveyor belts. This problem could be solved by placing guiding rolls on each side of the gripper arm. We had some bearings and some material left over that we used to make guiding rolls. We used lathe at school to produce two rolls and some aluminium plates as frame for guiding rolls since it is easy to deform into desirable shape. Guiding rolls were so placed in front of the feeding mechanism and are shown below in Figure 7.

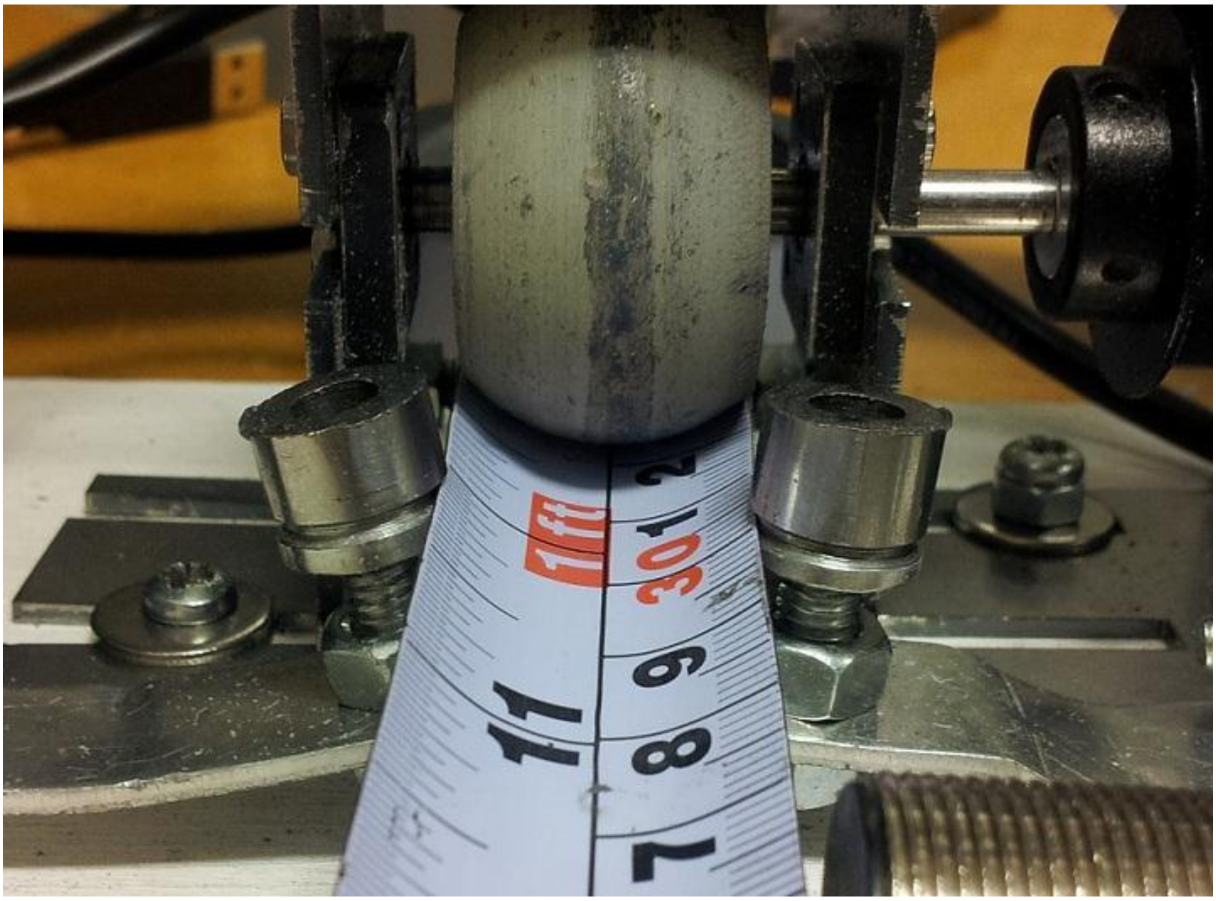

Figure 7: Guiding rolls.

This solution helped a lot and arm appeared to be very stable. There was also necessary to install sensor to stop gripper arm if it slips. Next step now is to install guiding rolls also on the top of the corner house. There is no time to make this upgrade before all documents has to be delivered. We are going to continue working with prototype until the final presentation and making documentation that can be helpful to Tronrud Engineering. Sensor attachment and location that also requires guiding rolls is shown below in Figure 8

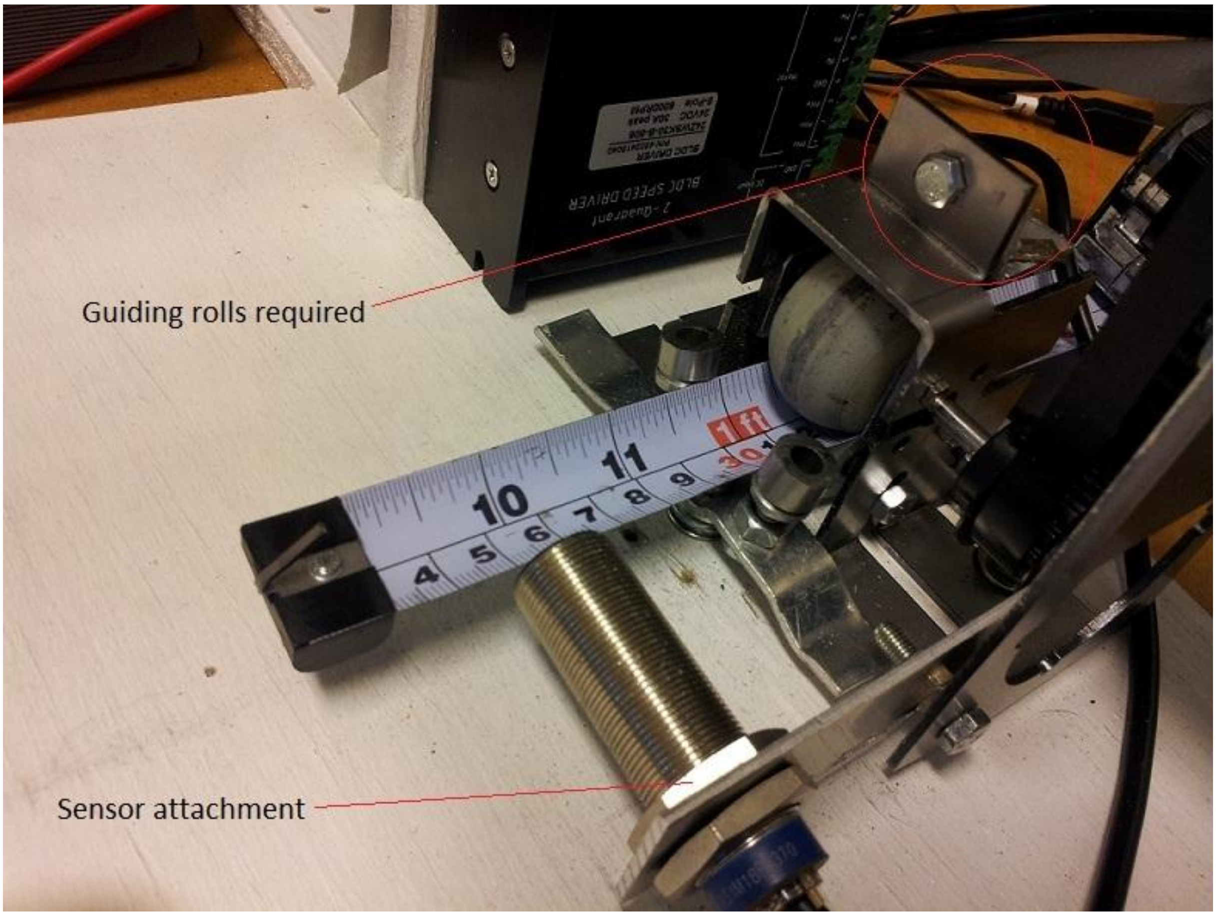

Figure 8: Guiding rolls and sensor attachment.

The thread selection consists of pulley wheels, timing belts and bearings with flanges shown in Figure 9. The module is shown assembled in Figure 10 with the Faulhaber.

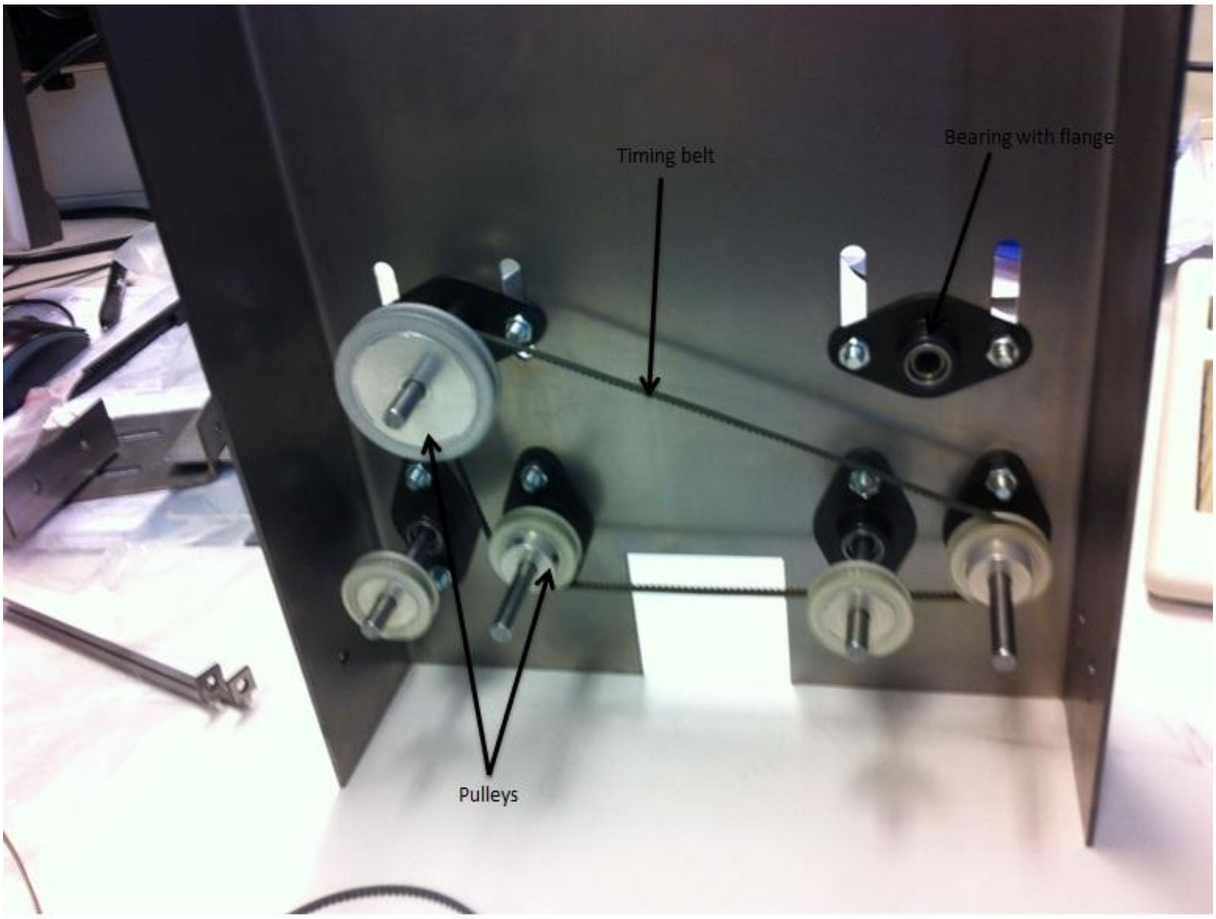

Figure 9: Thread Selection

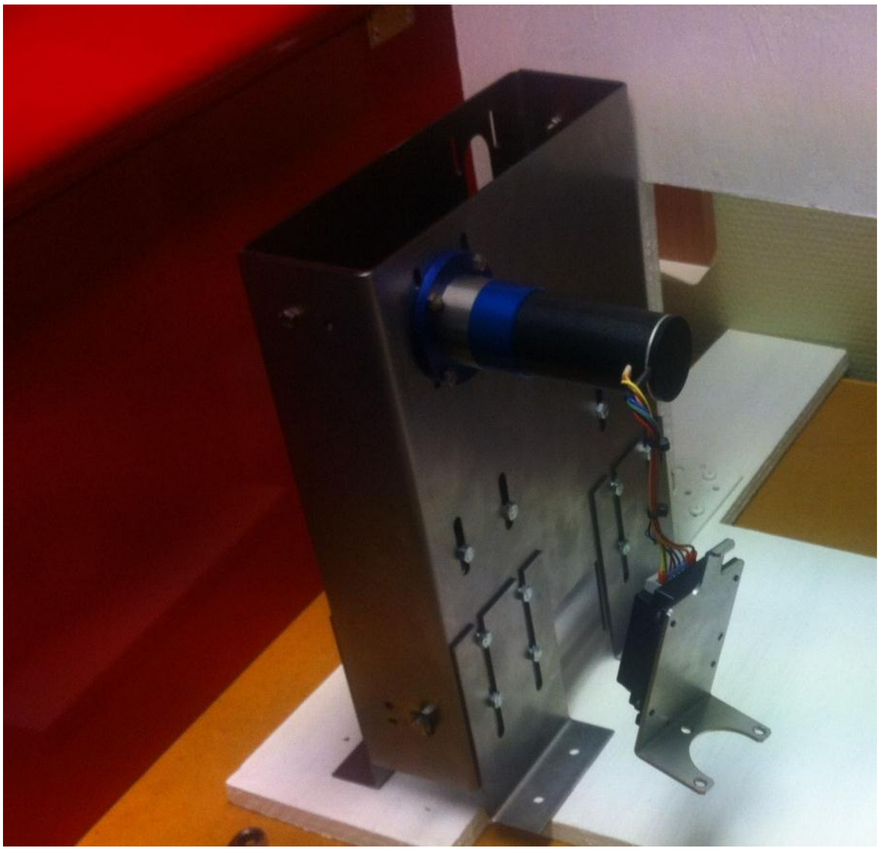

Figure 10: Thread Selection assembled

MODULE 21: HOLDER/CUTTER

The holder and cutter were made for having a functional prototype. It consists of a pliers and a scissor. The mechanism was first tested out with Lego and a description can be found in document D-00.A.21-EM. The holder and cutter are driven by a Faulhaber illustrated on Figure 1, the pliers and scissor on the inside is illustrated on Figure 12.

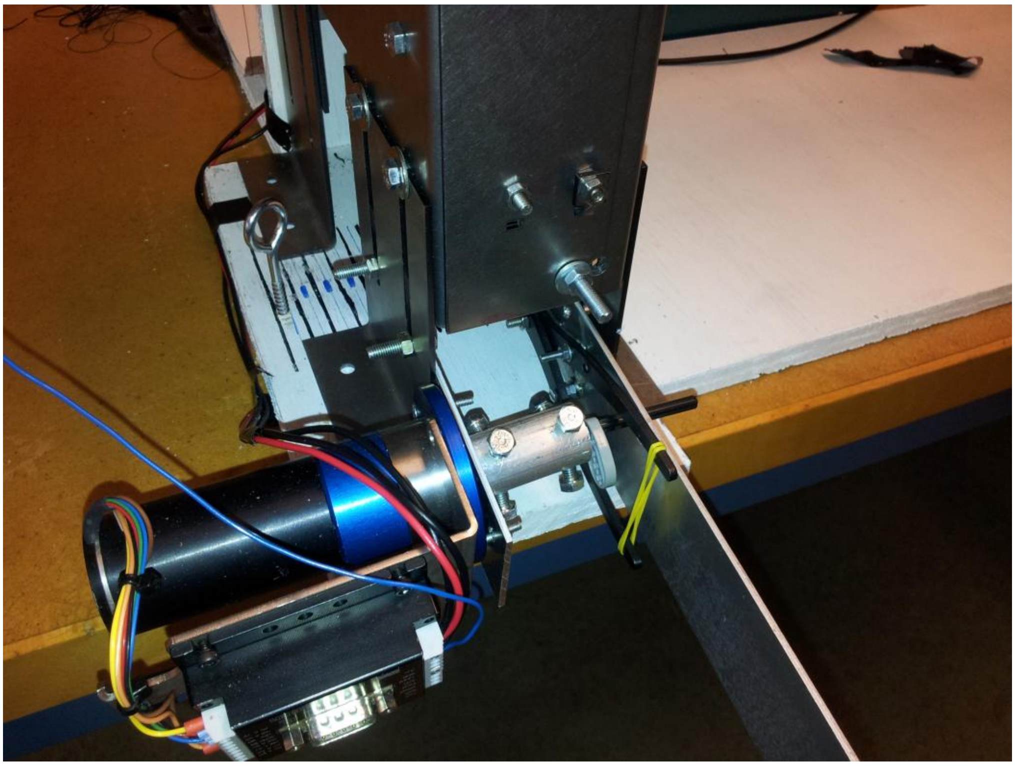

Figure 11: Holder/Cutter

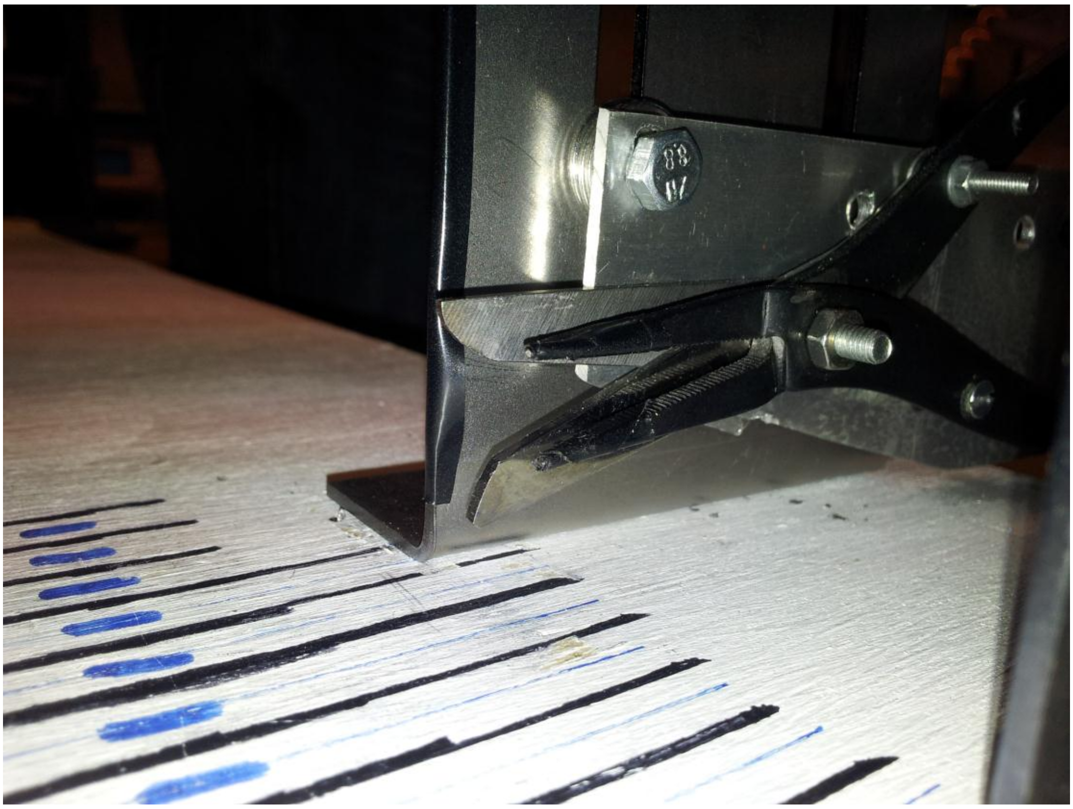

Figure 12: Holder/Cutter inside

MODULE 22: THREAD FEEDING SYSTEM

The thread feeding system consists simply of hooks and the thread sensor, as shown in Figure 13. These hooks are not ideal for guiding thread, because of gaps on the hooks itself, but tests show that they work fine. They are placed so that they guide the threads under the thread holding system and back under the sensor again. This is done to make a thread feeding system buffer of more than 1m in length, to secure the pick if the spools are empty.

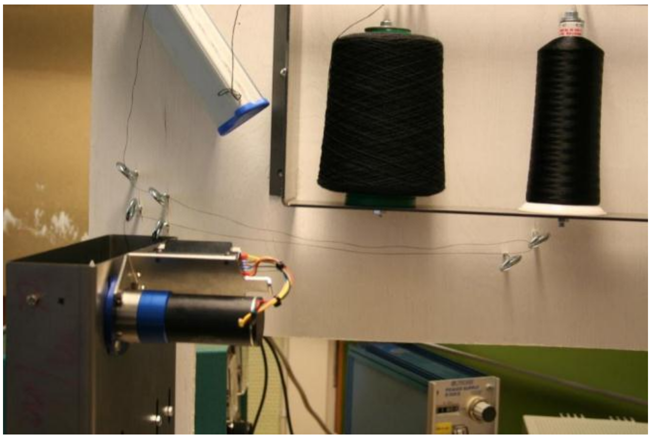

Figure 13: Thread feeding

MODULE 23: THREAD/SPOOL HOLDING SYSTEM

The thread/spool holding system is made out of 2.5mm sheet metal, and its thread tray is made out of 1mm sheet metal. The parts are made by Tronrud Engineering and Moss Jern og Stanseindustri.

Figure 14 shows the parts that were made.

Figure 14: Parts

Figure 15 shows the thread tray mounted.

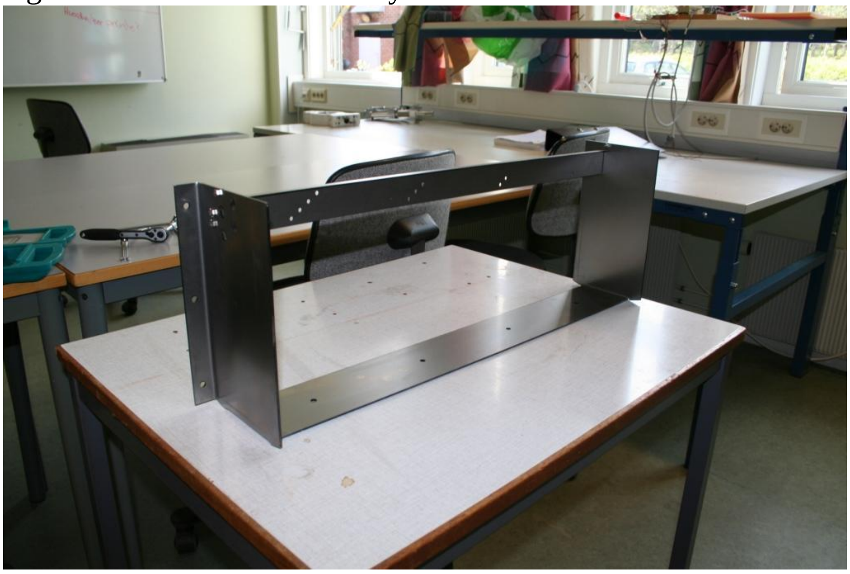

Figure 15: Mounted

Figure 16 shows the hooks being fastened to the thread tray. The hooks are from Biltema [1].

Figure 16: Hooks

Figure 17 illustrates how a spool is fitted by large washers on a threaded center pin. There were some small problems with centring the spool, but we sorted it.

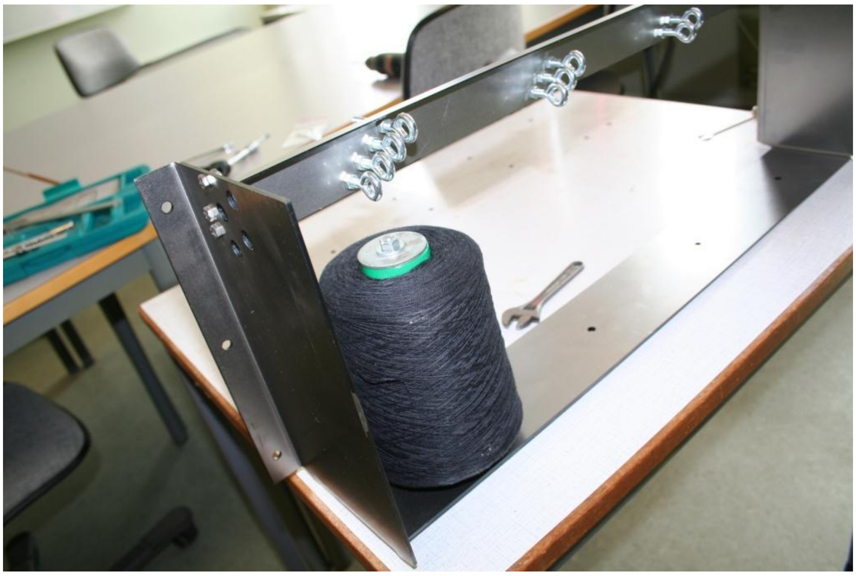

Figure 17: Spool

Figure 18 shows the assembled system, albeit not with the rotation arm, that we also got to be made.

Figure 18: System assembled

The chassis from plywood is actually a plan B construction, which replaces the original solution. All the other modules will be bolted and fastened to this chassis. It is made from 15mm thick plywood plates and is supported by brackets. Figure 19 and Figure 20 shows the building process.

Figure 19: Chassis

Figure 20: Chassis painted

SOURCES

[1]–Biltema http://biltema.no/no/

REQUIREMENTS FOR THE "AUTOMATIC SHUTTLE CONTROL SYSTEM"

D-02.A.09-A

Release 4.0

TRONRUD ENGINEERING AS

RELEASE NOTES

Date	Version	Description	Author
01.11.11	0.1	- First draft	All
08.11.11	0.2	- Changing req.spec. template	Mats Strand Sætervik Andreas Stustad Inge Ytre-Eide
15.11.2011	0.3	- Added requirements for modules 20 and 21	Inge Ytre-Eide Andreas Stustad
20.11.2011	0.4	- First draft mechanical	Vazgen Karlsen Andreas Vander
21.12.2011	0.5	- Modules 22 and 30.	Inge Ytre-Eide
22.11.2011	0.6	- Edited and created new reqs	Andreas Stustad
28.12.2011	0.7	- Added R-13.A.36-M	Andreas Stustad
29.12.2011	0.8	- Added R-12.A.53-M	Andreas Stustad
29.12.2011	0.9	- Modules 30 and 31. - Updated the style to the standard	Inge Ytre-Eide Eirik Nordstrand
29.12.2011	1.0	- All modules sewed together	Eirik Nordstrand
29.12.2011	1.1	- Edited and systemized requirements	Andreas Stustad
29.12.2011	1.1.1	- Edited requirement	Inge Ytre-Eide
02.01.2012	1.1.2	- Added module number on the front page.	Eirik Nordstrand
03.01.2012	1.2	- Added status field and test id field. - Divided into functional and non-functional requirements.	Vazgen Karlsen Andreas Vander
03.01.2010	1.2.1	- Spelling and grammar - Fixed the release notes	Eirik Nordstrand Eirik Nordstrand
04.01.2012	1.3	- Edited R-11.A.06-M, R-11.A.27-M - Deleted R-10.A.05-EM - Added R-10.A.54-EM, R-10.A.55-EM, R-31.A.56-E - Fixed page setup	Andreas Stustad
04.01.2012	1.4	- Fixed general styles - Fixed spacing in TOC - Updated TOC	Eirik Nordstrand
09.01.2012	2.0	- Finished document - Linked requirements to tests	Eirik Nordstrand Andreas Stustad

02.02.2012	2.1	Added requirements to thread sensor	Eirik Nordstrand
06.02.2012	2.2	Edited R-23.A.31-M, R-23.A.26-M Added R-22.A.60-M, R-40.A.61-M, R-40.A.62-M, R-40.A.63-M	Andreas Stustad
10.02.2012	2.1.1	Added requirements around thread selection	Inge Ytre-Eide Andreas Vander
23.02.2012	2.2.1	Added arm brake requirement	Eirik Nordstrand
27.02.2012	2.2.2	Added requirements for gripper arm and feeding mechanism. Module (11,12)	Vazgen Karlsen
08.03.2012	2.2.3	Changed and added requirements for feeding mechanism	Mats Strand Sætervik
08.03.2012	2.2.4	Edited R-23.A.26-M, R-23.A.68-EM , R-23.A.31-M Added R-23.B.77-EM	Andreas Stustad
14.03.2012	3.0	Finalized document	Eirik Nordstrand
01.05.2012	3.1	Added requirements for feeding mechanism, DAC	Mats Strand Sætervik
07.05.2012	3.1.1	Added module 14	Mats Strand Sætervik
08.05.2012	3.1.2	Cleaned up in twin posts, wrong posts Added matrix of requirements (status)	Andreas Stustad
16.05.2012	3.1.3	Updated R-11.A.70-M	Andreas Stustad
19.05.2012	3.2	Spelling and grammar	Eirik Nordstrand
20.05.2012	3.3	Edited: R-00.A.13-E , R-00.A.20-E, R-14.A.79-E, R-30.A.52-E Updated approve/not approve requirements	Mats Strand Sætervik
21.05.2012	3.3.1	Edited R-00.B.38-EM Updated requirements status module 23	Andreas Stustad
21.05.2012	3.3.2	Edited: R-10.A.01-M Updated approve/not approve requirements: R-10.A.01-M R-12.A.10-EM	Vazgen Karlsen
22.05.2012	3.3.3	Discarded: R-22.A.19-E Added R-22.A.87-E	Eirik Nordstrand
22.05.2012	3.3.4	Updated status on spool requirements	Andreas Stustad
23.05.2012	3.4	Added intro Added R-30.A.88-E	Andreas Stustad Eirik Nordstrand
26.05.2012	3.4.1	Added Test-ID for R-23.A.59-M	Eirik Nordstrand

28.05.2012	3.5	Removed R-00.A.20-E, R-10.A.02-EM	Andreas Stustad
29.05.2012	4.0	Updated and finalized document	Andreas Stustad

ABOUT THIS DOCUMENT

This document contains all the requirements that are set for our module. Some of the requirements are set by our employer, while other are set by the project group. Each requirement contains information about the date the requirement was set, who added the requirement, pointer to external document for more information, pointer to external test document, description of the requirement and the status for the requirement.

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INTRODUCTION

This requirement specification list up every requirement set about the module that we have built. Tronrud Engineering has come up with whishes for what the system shall do and look like, and these wishes have later become requirements. The requirements have been added, edited and deleted during the project. The deleted requirements can be seen in "List of used numbers" (D-00.B.12-A) or in past versions of the requirement specification.

There is a list of every requirement below, to help with order. This list shows the requirement code, its name, the creator, the tester and status. The list below shows which requirement is approved and not approved, as well as not tested.

The actual requirement specification is divided into non-functional requirements and functional requirement. Functional requirements describe functions, while non-functional requirements describe constraints. The requirements are also divided into modules or sub-systems to have order on where each requirement belongs in the system. Every module is listed in the document "Project Plan" (D-00.A.00-A). These are in addition, divided into A, B or C requirements, which describe the requirements importance in the project. Each requirement has a table, and each box in the requirement table has different information. The table lists the requirement code and name. The explanation for the code system is also given in the document "Project Plan" (D-00.A.00-A). The requirement table also shows the creator and its creation date. There is a box for relations to other documents, in the box "document number", and a box that list up the test(s) for each requirement. The test can be seen in the document "Test specification" (D-03.A.08-A). The box with text is the actual requirement, and the last box is for the status. The status shows if the requirement is tested or not and has more information if it is needed.

REQUIREMENT LIST

Here is a list of every requirement set. These requirements are explained in detail below in the actual requirement specification. The list below shows which requirements are fulfilled, which are partly fulfilled and which are not fulfilled.

Req. Nr.	Req. Name	By	Tester	Status
Non-functional				
A-req.				
R-00.A.13-E	Emergency button	IYE	MSS	Not approved
R-00.A.39-EM	Replacing skills	AS		Not approved
R-10.A.00-EM	Success rate	All		Not approved
R-10.A.01-M	Lifetime	All	VK	Approved
R-10.A.54-EM	Gripper height	AS		Approved
R-10.A.55-EM	Gripper width	AS		Approved
R-11.A.06-M	Arm length	All		Approved
R-11.A.07-M	Storage space	All		Approved
R-11.A.08-M	Lifetime	All		Not approved
R-11.A.09-M	Gripper arm weight	All		Not approved
R-11.A.27-M	Arm width	All		Approved
R-11.A.35-M	Arm height	All		Approved
R-11.A.69-M	Gripper arm strength	VK		Not approved
R-11.A.70-M	Gripper arm cross-section	VK		Approved
R-11.A.71-M	Fixing points gripper arm	VK		Not approved
R-12.A.10-EM	Lifetime	All		Approved
R-12.A.53-M	Strength	AS		Approved
R-12.A.72-M	Adjustment of free wheels	All		Approved
R-12.A.73-M	Feeding mechanism adjustment	All		Approved
R-14.A.78-E	Voltage regulator spec	MSS	MSS	Not approved
R-14.A.81-E	Voltage follower spec	MSS	MSS	Approved
R-14.A.83-E	DAC spec	MSS	MSS	Approved
R-20.A.14-EM	Speed	IYE, AS		Not approved
R-20.A.18-EM	Lifetime	IYE,		Approved

		AS		
R-20.A.64-EM	Individual operation	IYE		Not approved
R-20.A.65-EM	Position error	IYE		Approved
R-21.A.22.EM	Lifetime	IYE, AS		Not approved
R-21.A.23-EM	Safety	IYE, AS		Not approved
R-21.A.66-M	Accuracy	AV		Not approved
R-22.A.25-M	Lifetime	AV, VK		Not approved
R-22.A.36-M	Thread feeding success	AS		Not approved
R-22.A.60-M	Thread feeding buffer	AS	AS, EN	Approved
R-22.A.86-E	Halt on multiple threads	AS, EN	AS, EN	Approved
R-22.A.87-E	Thread feeding notify	AS	AS, EN	Approved
R-23.A.30-M	Lifetime	AV, VK		Not approved
R-23.A.31-M	Spool variation	AS	AS	Approved
R-23.A.59-M	Thread resistance	EN, AS	AS, EN	Not approved
R-23.A.68.EM	Arm brake	EN		Not approved
R-30.A.44-E	Operational voltage	IYE	MSS	Approved
R-30.A.52-E	Emergency shutdown	IYE	-	Not approved
R-30.A.85-E	Serial communication with Faulhaber	IYE	IYE	Approved
R-31.A.51-E	Spool size	IYE		Approved
R-31.A.56-E	Door safety	AS	MSS and EN	Approved
R-31.A.57-E	Yarn sensor – input voltage	EN		Approved
R-31.A.58-E	Yarn sensor – output voltage	EN		Approved
R-40.A.32-M	Design	AV, VK	AS	Not approved
R-40.A.33-M	Maintenance	AV, VK	AS	Not approved
R-40.A.34-M	Durability	AV, VK	AS	Approved
R-40.A.37-M	Fixing points	AS	AS	Not approved
R-40.A.61-M	Casing thickness	AS	AS	Not approved

R-40.A.62-M	Chassis thickness	AS	AS	Approved
R-40.A.63-M	System mounting	AS	AS	Approved
B-req.				
R-10.B.03-M	Replace time	All		Approved
R-10.B.04-EM	Replace skills	All		Not approved
R-12.B.75-EM	Start/stop point	MSS		Not approved
R-23.B.77-EM	Spool variation	AS	AS	Approved
C-req.				
R-12.C.76-E	Travel speed	MSS	MSS	Approved
Functional				
A-req.				
R-20.A.16-EM	Capacity	IYE, AS		Not approved
R-20.A.17-EM	Compatibility	IYE, AS		Not approved
R-20.A67-EM	Compatibility	IYE, AS		Not approved
R-23.A.26-M	Capacity	AV, VK	AS	Not approved
R-23.A.28-E	Notify	AV,VK	AS, EN	Approved
R-30.A.88-E	Analog comparator voltages	EN	EN	Approved
B-req.				
R-00.B.24-E	System reset	IYE		Not approved
R-00.B.38-EM	Replacing spool	AS		Not approved

NON-FUNCTIONAL REQUIREMENTS

A-REQUIREMENTS

THE ENTIRE SYSTEM

R-00.A.13-E EMERGENCY BUTTON	
Document number: D-03.A.20-A	**Date:** 21.12.2011
Test id:T-00.A.25-E	**By:** IYE
When the emergency button is pushed, the system shall halt at once.	
Status: Not approved	

R-00.A.39-EM SPOOL REPLACING SKILLS	
Document number:	**Date:** 29.12.2011
Test id:T-00.A.24-EM	**By:** AS
Changing the spool and laying the new threads should not require any technical knowledge.	
Status: Not approved	

GRIPPER

R-10.A.00-EM	SUCCESS RATE	
Document number:		**Date:** 01.11.2011
Test id:T-10.A.12-EM		**By:** All
The gripper shall never fail to grab the thread more than 1 out of 1000 cycles, i.e. 1‰		
Status: Not approved		

R-10.A.01-M	LIFETIME	
Document number:	D-03.A.31-M, D-03.A.20-A	**Date:** 01.11.2011
Test id:T-10.A.13-M		**By:** All
The gripper should have a lifetime of at least 1 year or 1875 working hours. Calculation of cycles per year: 25 cycles/min ·60min = 1500 cycles/hour. 1875 working hours ·1500 cycles/hour = 2 812 500 cycles.		
Status: Approved		

R-10.A.54-EM GRIPPER HEIGHT	
Document number: D-00.A.11-EM, D-03.A.20-A	**Date:** 04.01.2012
Test id:T-10.A.32-EM, T-10.A.33-EM	**By:** AS
The height of the gripper shall be far less than 19,2mm	
Status: Approved	

R-10.A.55-EM GRIPPER WIDTH	
Document number: D-00.A.11-EM, D-03.A.20-A	**Date:** 04.01.2012
Test id:T-10.A.34-EM, T-10.A.35-EM	**By:** AS
The width of the gripper shall be far less than 157,3mm / 2 = 78,5mm This is half of the shed width.	
Status: Approved	

GRIPPERARM

R-11.A.06-M ARM LENGTH	
Document number: D-00.A.11-EM	**Date:** 01.11.2011
Test id:T-11.A.00-M, T-11.A.01-M	**By:** All
The length of the arm shall be at least 1000mm	
Status: Approved	

R-11.A.07-M STORAGE SPACE	
Document number: D-00.A.10-M	**Date:** 01.11.2011
Test id:T-11.A.06-M, T-11.A.07-M	**By:** All
The storage space for the gripper arm is limited by the total area for the module.	
Status: Approved	

R-11.A.08-M LIFETIME	
Document number:	**Date:** 01.11.2011
Test id:T-11.A.08-M, T-11.A.09-M	**By:** All
The gripper arm should have a lifetime of at least of 5 years or 8750 working hours. Calculation of cycles per lifetime: 25 cycles/min · 60min =1500 cycles/hour. 8750 working hours · 1500 cycles/hour = 13 125 000 cycles.	
Status: Not approved	

R-11.A.09-M GRIPPER ARM WEIGHT	
Document number: D-00.A.18-EM	**Date:** 01.11.2011
Test id: T-11.A.11-M	**By:** All
The gripper arm must be so light that it does not affects the rest of the system i.e. electrical motors or warps. Maximum allowed mass is 300g.	
Status: Not approved	

R-11.A.27-M ARM WIDTH	
Document number: D-00.A.11-EM	**Date:** 01.11.2011
Test id:T-11.A.02-M, T-11.A.03-M	**By:** All
The width of the arm shall be far less than 157.3mm · 0,8= 125,8mm	
Status: Approved	

R-11.A.35-M ARM HEIGHT	
Document number: D-00.A.11-EM	**Date:** 01.11.2011
Test id:T-11.A.04-M, T-11.A.05-M	**By:** All
The height of the arm shall be far less than 19,2mm.	
Status: Approved	

R-11.A.69-M GRIPPER ARM STRENGTH	
Document number:	**Date:** 02.02.2012
Test id: T-11.A.79-M	**By:** VK
The gripper arm shall withstand the bend stresses that occur.	
Status: Not approved	

R-11.A.70-M GRIPPER ARM CROSS SECTION	
Document number:	**Date:** 02.02.2012
Test id: T-11.A.80-M	**By:** VK
Cross section area of the gripper arm shall be 2,5mm · 0,2mm with 14.4mm as radius.	
Status: Approved	

R-11.A.71-M FIXING POINTS GRIPPER ARM	
Document number:	**Date:** 02.02.2012
Test id: T-11.A.81-M and T-11.A.82-M	**By:** VK
The gripper arm shall contain fixing points that match fixing points for the gripper.	
Status: Not approved	

FEEDING MECHANISM FOR GRIPPERARM

R-12.A.10-EM LIFETIME	
Document number: D-03.A.31-M	**Date:** 01.11.2011
Test id: T-12.A.16-EM	**By:** All
The feeding mechanism should have a lifetime of at least 1 year or 1875 working hours. Calculation of cycles per lifetime: 25 cycles/min · 60min =1500 cycles/hour. 1875 working hours · 1500 cycles/hour = 2 812 500 cycles.	
Status: Approved	

R-12.A.53-M STRENGTH	
Document number:	**Date:** 29.12.2011
Test id:T-12.A.19-M	**By:** AS
The feeding mechanism for the gripper arm shall withstand the stresses that occurs when the system stops suddenly or power loss.	
Status: Approved	

R-12.A.72-M ADJUSTMENT OF FREE WHEELS	
Document number:	**Date:** 01.11.2011
Test id: T-12.A.83-M and T-12.A.84-M	**By:** All
Free wheels (support wheels) around pulley wheel for the gripper arm shall be adjustable in the direction of pulley wheels centre. Adjustable range of minimum 3mm.	
Status: Approved	

R-12.A.73-M FEEDING MECHANISM ADJUSTMENT	
Document number:	**Date:** 01.11.2011
Test id: T-12.A.85-M and T-12.A.86-M	**By:** All
The whole feeding mechanism shall be adjustable in x, y and z direction. Adjustable range of minimum 10mm in each direction.	
Status: Approved	

DAC CIRCUIT, FEEDING MECHANISM FOR GRIPPER ARM

R-14.A.78-E VOLTAGE REGULATOR SPECIFICATIONS	
Document number:	**Date:** 01.05.2011
Test id: T-14.A.90-E	**By:** MSS
The following specification needs to be satisfied: - Voltage in: 24 V +/- 0,5 V - Voltage out: 12 V +/- 0,3 V - The voltage regulator has to deliver enough effect to power the 12 V circuit.	
Status: Not approved	

R-14.A.81-E VOLTAGE FOLLOWER SECIFICATIONS	
Document number:	**Date:** 01.05.2011
Test id: T-14.A.92-E	**By:** MSS
The following specification needs to be satisfied: - Got to operate on voltage supply 12 V +/- 1 Volts - The operational amplifier has to support rail to rail output. - Has to response as fast as the DAC. The output voltage has to change as fast as the output voltage of DAC.	
Status: Approved	

R-14.A.83-E DAC SPECIFICATIONS	
Document number:	**Date:** 01.05.2011
Test id: T-14.A.93-E, T-14.A.98-E	**By:** MSS
The following specification needs to be satisfied: - The DAC have to be a 8 bit parallel DAC - Got to operate on voltage supply 12 V +/- 1 Volts - The DAC has to deliver a voltage output in the range of 0 -5 V +/- 0.1 Volt.	
Status: Approved	

THREAD SELECTION SYSTEM

R-20.A.14-EM SPEED	
Document number:	**Date:** 15.11.2011
Test id:T-20.A.36-EM	**By:** IYE, AS
The selection system will have the next thread ready before the gripper arm comes to pick it up, i.e. there should not be a delay for the system.	
Status: Not approved	

R-20.A.18-EM LIFETIME	
Document number:	**Date:** 15.11.2011
Test id:T-20.A.40-EM	**By:** IYE, AS
The thread selection system shall have a lifetime of at least 5 years or 8750 working hours. Calculation of cycles per lifetime: 25 cycles/min · 60min =1500 cycles/hour. 8750 working hours · 1500 cycles/hour = 13 125 000 cycles.	
Status: Approved	

R-20.A.64-EM INDIVIDUAL OPERATION	
Document number:	**Date:** 10.02.2012
Test id: T-20.A.74-EM	**By:** IYE
Each arm should operate individually and not affect the other arms.	
Status: Not approved	

R-20.A.65-EM POSITION ERROR	
Document number:	**Date:** 10.02.2012
Test id: T-20.A.75-EM	**By:** IYE
The thread selection system shall place the selected thread so that the gripper is able to pick it up and not fail at this more than 1 of 1000 cycles.	
Status: Approved	

THREAD CUTTING SYSTEM

R-21.A.22-EM LIFETIME	
Document number:	**Date:** 15.11.2011
Test id:T-21.A.42-EM, T-21.A.43-EM, T-21.A.44-EM	**By:** IYE, AS
The thread cutting system should have a lifetime of at least 1 year or 1750 working hours. Calculation of cycles per year: 25 cycles/min · 60min =1500 cycles/hour. 1750 working hours · 1500 cycles/hour = 2 625 000 cycles.	
Status:	

R-21.A.23-EM SAFETY	
Document number:	**Date:** 15.11.2011
Test id:T-21.A.45-EM	**By:** IYE, AS
It shall not be possible to insert any objects with diameter bigger than 0.5cm.	
Status:	

R-21.A.66-M ACCURACY	
Document number:	**Date:** 10.02.2012
Test id: T-20.A.76-EM	**By:** AV
The cutter shall not fail to cut the thread more than once for each 1000 cycle.	
Status:	

THREAD FEEDING SYSTEM

R-22.A.25-M LIFETIME	
Document number:	**Date:** 20.11.2011
Test id:T-22.A.46-EM	**By:** AV, VK
The thread feeding system should have a lifetime of at least 5 years or 8750 working hours.	
Status: Not approved	

R-22.A.36-M THREAD FEEDING SUCCESS	
Document number:	**Date:** 28.12.2011
Test id:T-22.A.47-EM	**By:** AS
Threads shall never fail to be delivered or snap more than 1 out of 1000 cycles, i.e. 1‰.	
Status: Not approved	

R-22.A.60-M THREAD FEEDING BUFFER	
Document number:	**Date:** 06.02.2012
Test id: T-22.A.70-M	**By:** AS
The thread feeding path shall be longer than the longest pick, so that the ongoing pick can be finished before changing spool/thread.	
Status: Approved	

R-22.A.86-E HALT ON MULTIPLE THREADS	
Document number:	**Date:** 22.05.2012
Test id: T-22.A.94-E	**By:** AS, EN
The gripper shall halt within 10cm if multiple threads are pulled. The user will then have to press SW0-button to get the gripper back to its initial position.	
Status: Approved	

R-22.A.87-E THREAD FEEDING NOTIFY	
Document number:	**Date:** 29.12.2011
Test id:T-22.A.48-E	**By:** AS
The gripper shall reduce its speed if a thread are failed to be delivered or snapped, and keep this reduced speed until it reaches its initial position.	
Status: Approved.	

THREAD HOLDING SYSTEM

R-23.A.30-M LIFETIME	
Document number:	**Date:** 20.11.2011
Test id:T-23.A.50-M	**By:** AV, VK
The thread holding system should have a lifetime of at least 5 years or 8750 working hours.	
Status: Not approved	

R-23.A.31-M SPOOL VARIATION	
Document number:	**Date:** 20.11.2011
Test id:T-23.A.51-M	**By:** AS
The thread holding system shall be able to hold conical spools. The maximum spool size is 11 cm in diameter and 15 cm in height.	
Status: Approved	

R-23.A.59-M THREAD RESISTANCE	
Document number: D-00.A.18-EM	**Date:** 06.02.2012
Test id: T-23.A.68-M, T-23.A.99-M,	**By:** EN, AS
The threads must be easily pulled off the spools. The spools are vertical and not rotating.	
Status: Not approved	

R-23.A.68-EM ARM BRAKE	
Document number:	**Date:** 23.02.2012
Test id: T-23.A.78-EM	**By:** EN
If used cylindrical spools, the rotating arm shall not rotate more than 45 degrees after the thread is no longer moving.	
Status: Not approved	

CONTROLL UNIT

R-30.A.44-E OPERATRIONAL VOLTAGE	
Document number:	**Date:** 21.12.2011
Test id:T-30.A.54-E	**By:** IYE
The operational voltage of the microcontroller shall be 12v or less.	
Status: Approved	

R-30.A.52-E EMERGENCY SHUTDOWN	
Document number:	**Date:** 29.12.2011
Test id:T-30.A.58-E	**By:** IYE
The microcontroller shall halt the system immediately if the user presses the emergency shutdown button.	
Status: Not approved	

R-30.A.85-E SERIAL COMMUNICATION WITH FAULHABER	
Document number:	**Date:** 28.04.2012
Test id: T-30.A.89-E	**By:** IYE
The microcontroller shall communicate with the Faulhaber MCBL 2805 by serial on a 9600 baud rate	
Status: Approved	

SENSORS

R-31.A.51-E SPOOL SIZE	
Document number:	**Date:** 29.12.2011
Test id:T-31.A.62-E	**By:** IYE
There shall be sensors for each spool to warn the system when it is, or soon is, no more thread on the spool.	
Status: Approved	

R-31.A.56-E DOOR SAFETY	
Document number:	**Date:** 04.01.12
Test id:T-31.A.63-E	**By:** AS
The system shall halt when maintenance doors for the spools are open.	
Status: Approved	

R-31.A.57-E YARN SENSOR - INPUT VOLTAGE	
Document number:	**Date:** 02.02.12
Test id: T-31.A.66-E	**By:** EN
The sensor shall be turned on when 24 volt is connected.	
Status: Approved	

R-31.A.58-E YARN SENSOR - OUTPUT VOLTAGE	
Document number:	**Date:** 02.02.12
Test id: T-31.A.67-E	**By:** EN
The sensor shall give a constant output while the thread is moving, and give another voltage when the thread is not moving. It should also give an individual voltage if too many threads are moving.	
Status: Approved	

CASING

R-40.A.32-M DESIGN	
Document number: D-00.A.10-M	**Date:** 20.11.2011
Test id:T-40.A.20-M	**By:** AV,VK
The casing should match existing design of the TC2, within the limitations set by Tronrud Engineering.	
Status: Not approved	

R-40.A.33-M MAINTENANCE	
Document number: D-09.A.14-A	**Date:** 20.11.2011
Test id:T-40.A.21-M	**By:** AV,VK
The casing shall be equipped with doors so that accessing the spools and threads are easy.	
Status: Not approved	

R-40.A.34-M DURABILITY	
Document number:	**Date:** 20.11.2011
Test id:T-40.A.22-M	**By:** AV,VK
The attachments of the casing should be robust enough to carry the modules weight and vibrations in operation.	
Status: Approved	

R-40.A.37-M FIXING POINTS	
Document number: D-04.A.03-A	**Date:** 22.11.2011
Test id:T-40.A.23-M	**By:** AS
The fixing points for the casing and the module shall use the four 6mm existing bolt holes for the front plate of the TC2.	
Status: Not approved	

R-40.A.61-M CASING THICKNESS	
Document number:	**Date:** 06.02.2012
Test id:T-40.A.71-M	**By:** AS
The casing shall consist of 1 mm thick steel plates, as the rest of the panels on the TC2.	
Status: Not approved	

R-40.A.62-M CHASSIS THICKNESS	
Document number:	**Date:** 06.02.2012
Test id: T-40.A.72-M	**By:** AS
The chassis or back plate of the casing shall be 2.5 mm thick.	
Status: Approved	

R-40.A.63-M SYSTEM MOUNTING	
Document number:	**Date:** 06.02.2012
Test id: T-40.A.73-M	**By:** AS
The system and its parts shall be mounted to the chassis plate or back plate.	
Status: Approved	

B-REQUIREMENTS

GRIPPER

R-10.B.03-M	REPLACE TIME
Document number:	**Date:** 1.11.2011
Test id:T-10.B.27-M	**By:** All
Replacing the gripper shouldn't take more than 20 minutes.	
Status: Approved	

R-10.B.04-EM	REPLACE SKILLS
Document number:	**Date:** 1.11.2011
Test id:T-10.B.28-EM	**By:** All
Replacing the gripper shouldn't require any technical education/knowledge.	
Status: Not approved	

FEEDING MECHANISM FOR GRIPPERARM

R-12.B.75-EM	GRIPPER STOP/START POINT
Document number:	**Date:** 08.03.2012
Test id:T-12.A.17-EM, T-12.A.96-EM	**By:** MSS
The feeding mechanism has to start and stop the gripper arm at the same point each cycle. An acceptable error is defined by +/- 5 mm in relation to the start/stop point. The endpoint is defined as 5 mm behind the thread selection rear wall at pickup.	
Status: Not approved	

THREAD HOLDING SYSTEM

R-23.B.77-EM SPOOL VARIATION

Document number:	**Date:** 08.03.2012
Test id:T-23.B.88-EM	**By:** AS

The thread holding system must be able to use cylindrical spools.

Status: Approved

C-REQUIREMENTS

R-12.C.76-E GRIPPER TRAVEL SPEED

Document number:	**Date:** 08.03.2012
Test id:T-12.A.18-E, T-12.A.97-EM	**By:** MSS

The feeding mechanism has to propel the gripper and gripper arm across the shed and back again within 1 second. The acceleration and top speed has to be calculated accordingly to meet this requirement.

Status: Approved

FUNCTIONAL REQUIREMENTS

A-REQUIREMENTS

THREAD SELECTION SYSTEM

R-20.A.16-EM CAPACITY	
Document number:	**Date:** 15.11.2011
Test id:T-20.A.65-EM	**By:** IYE, AS
The system must be able to manage at least 8 different threads.	
Status: Not approved	

R-20.A.17-EM COMPATIBILITY	
Document number:	**Date:** 15.11.2011
Test id:T-20.A.64-EM	**By:** IYE, AS
The system will be able to handle all types of threads as can be used on the TC2.	
Status: Not approved	

R-20.A.67-EM	COMPATIBILITY
Document number: D-00.A.10-M	**Date:** 10.02.2012
Test id: T-20.A.77-EM	**By:** IYE, AS
The system shall not exceed the limitations given by Tronrud engineering	
Status: Not approved	

THREAD HOLDING SYSTEM

R-23.A.26-M	CAPACITY
Document number:	**Date:** 20.11.2011
Test id:T-23.A.52-M	**By:** AV, VK
The thread holding system must be able to hold 8 spools. The spools are maximum 11 cm in diameter and 15 cm in height.	
Status: Not approved.	

R-23.A.28-E NOTIFY	
Document number:	**Date:** 20.11.2011
Test id:T-23.A.53-E	**By:** AV, VK
The thread holding system will notify the user when spools are becoming empty.	
Status: Approved.	

CONTROLL UNIT

R-30.A.88-E ANALOG COMPARATOR INPUT VOLTAGES	
Document number:	**Date:** 01.05.2012
Test id:T-30.A.95-E	**By:** Eirik Nordstrand
The analog comparator output (ACO) shall be low when the voltage from the weft sensor is lower than the reference voltages (0.5V and 1.3V), and vice versa.	
Status: Approved	

B-REQUIREMENTS

THE ENTIRE SYSTEM

R-00.B.24-E SYSTEM RESET	
Document number:	**Date:** 21.12.2011
Test id:T-00.B.31-E	**By:** IYE
When the emergency button is pushed, the system shall halt at once.	
Status: Not approved	

R-00.B.38-EM REPLACING SPOOL	
Document number: D-09.A.14-A	**Date:** 29.12.2011
Test id: T-00.B.30-EM	**By:** AS
The whole sequence of changing a spool and laying the thread through the thread feeding system shall take no more than 5 minutes.	
Status: Not approved	

TEST PLAN FOR THE "AUTOMATIC SHUTTLE CONTROL SYSTEM"

D-03.A.30-A

Release 1.0

RELEASE NOTES

Date	Version	Description	Author
03.05.2012	0.1	Created test plan document and added some preplanned documentation.	Vazgen Karlsen
04.05.2012	0.2	Added table of tests for each phase and edited plan.	Vazgen Karlsen
14.05.2012	0.2.1	Added AS and (AS/EN) to “assigned to” for tests	Andreas Stustad
20.05.2012	0.3	Spelling and Grammar	Eirik Nordstrand
22.05.2012	0.3.1	Added test for module 22.	Eirik Nordstrand
22.05.2012	0.3.2	Updated status for module 22/23	Andreas Stustad
23.05.2012	0.3.3	Added test T-30.A.95-E	Eirik Nordstrand
26.05.2012	0.3.4	Added test T-23.A.99-M, T-23.A.100-M, T-23.A.101-M, T-23.A.102-M, T-23.A.103-M	Eirik Nordstrand
28.05.2012	0.3.5	Added progress several for tests.	Vazgen Karlsen
29.05.2012	1.0	Finalized document	Eirik Nordstrand

ABOUT THIS DOCUMENT

This document addresses the project's test strategy. Where it is divided into 4 phases

- Design test
- Module test
- Integration test
- Full system test

In each phase, modules shall be tested in different scenarios. E.g. stress, compatibility. Every test is subjected to white-box testing. Full system test includes also black-box testing, which will be executed if all parts arrive early in the 2^{nd} construction iteration.

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INTRODUCTION

The purpose with this document is to set the guidelines to how we're going to run the tests and the goal of these tests. This document sets the timeline of the different phases and is a key document to the development of the ASCS for the TC2 made by Tronrud Engineering.

TEST STRATEGY

Every requirement shall generate at least one test. As the phases are underway we might see the need for more requirements. The new requirements will then be added to the system requirements document and tested. Each module shall be tested multiple times during each phase, with different setup, to provoke errors and bugs. One test might also be the result of multiple requirements.

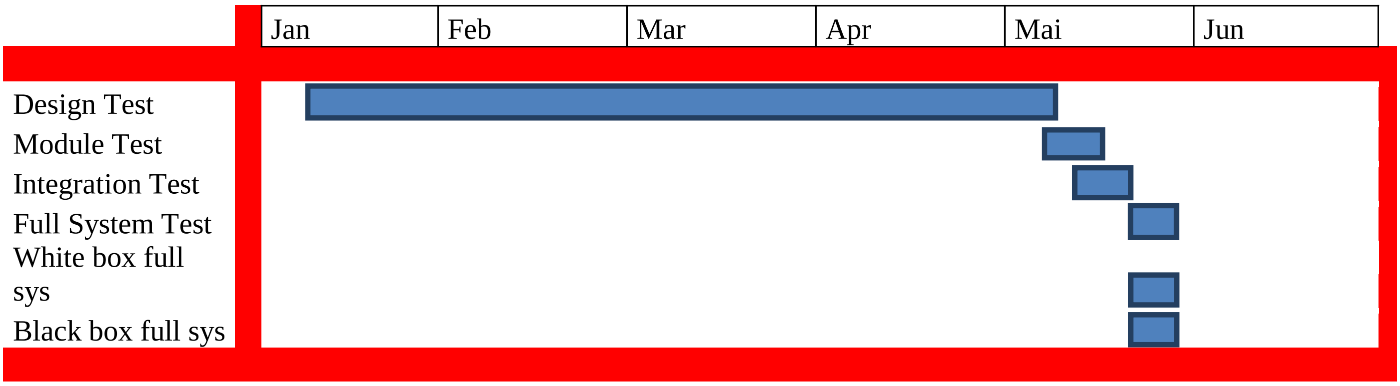

Figure 1: Timetable

The figure above shows our planned progress for the testing. The reason for late start of the physical module testing is the late delivery of parts. The parts have to be ordered by the end of February/beginning of March, so that Tronrud can be able to deliver them in time for construction and continuous testing of the system. I.e. per today, if the order is delivered by the deadline, we should have our parts by mid-April. There is still a chance that we can order parts after deadline. If all parts are not arrived before middle of May, then we have to continue project with the Lego prototype.

TEST PHASES

This project is going to include 4 test phases.

- Design tests
- Module tests
- Integration tests
- Full system tests

DESIGN TEST

This test should be done on each module in the design phase, i.e. when the modules are on the drawing board. The modules shall also be tested together as a whole system, divided into mechanical and electrical parts. The whole electrical system and the mechanical system has to be tested separately since no known program can simulate both at the same time. Design test shall be done thoroughly to hinder later system bugs. Detection of bugs or design failures in this phase is far less time-consuming to fix than later on in the project, where parts and assemblies already is made and tested. These design tests are a reason for delays the development of the affected module. The results of this delay is the pushback of the full system test, and maybe even delay the project, so much that we might never see a prototype. The design tests are run in simulation software, e.g. Multisim (circuit design program) and SolidWorks (3D design program). This project can be divided into two groups, mechanical modules and electrical modules. Tests that shall be done in this phase are divided into two groups:

1. Inge Ytre-Eide, Mats Strand Sætervik and Eirik Nordstrand for electrical modules.
2. Andreas Vander, Andreas Stustad and Vazgen Karlsen for mechanical modules.

MECHANICAL DESIGN TESTS

It is important here to test the strength and durability of the materials used, so the following qualities should be simulated and optimized:

- Stress
- Lifespan/fatigue
- Functionality
- Cost
- Measurements
- Capacity

ELECTRICAL DESIGN TESTS

This testing is mainly focused around functionality, size and cost. This is a continuous process when designing the circuitry. The following qualities shall be simulated and optimized

- Speed
- Power requirement
- Robustness
- Calculations

PROGRESS PERCENTAGE EXPLANATION	
0%	Testing is not started
50%	Testing is in progress
100%	Testing is complete

The table below is a summary of all design tests that shall be done. Each test number includes fields of progress and test responsible. All test specifications can be found in “D-03.A.08-A” and test reports can be found in “D-03.A.20-A” document.

DESIGN TESTING LIST

Test number:	Test description:	Assigned to:	Progress:
T-10.A.13-M	Gripper lifetime FEM	VK	100%
T-10.A.32-EM	Gripper height SW measure	VK	100%
T-10.A.34-EM	Gripper width SW measure	VK	100%
T-11.A.00-M	Gripper arm length SW measure	VK	100%
T-11.A.02-M	Gripper arm width SW measure	VK	100%
T-11.A.04-M	Gripper arm height SW measure	VK	100%
T-11.A.06-M	Gripper arm storage space SW	VK	100%
T-11.A.08-M	Gripper arm lifetime FEM	VK	100%
T-11.A.79-M	Gripper arm strength FEM	VK	100%
T-11.A.80-M	Gripper arm cross section	VK	100%
T-11.A.81-M	Gripper arm fixing points SW measure	VK	100%
T-12.A.16-EM	Feeding mechanism for gripper arm lifetime	VK	100%
T-12.A.19-M	Power loss stress analysis	VK	100%
T-12.A.83-M	Adjustment of free wheels SW measure	VK	100%
T-12.A.85-M	Feeding mechanism adjustment SW measure	VK	100%
T-20.A.40-EM	Thread selection lifetime (FEM)	AV	100%
T-20.A.77-EM	Size SW measure	AV	100%
T-21.A.42-EM	Thread cutter lifetime FEM	AV/VK	0%
T-22.A.70-M	Thread feeding buffer	AS/EN	100%
T-23.A.50-M	Thread holding system lifetime	AS/EN	0%
T-23.A.52-M	Capacity of managing 8 spools	AS/EN	100%
T-23.A.68-M	Thread pull resistance	AS/EN	100%
T-23.A.99-M	Thread Resistance - Straight off cylindrical spools	AS/EN	100%
T-23.A.100-M	Thread Resistance - Cylindrical spool with arm	AS/EN	100%
T-23.A.101-M	Thread Resistance - With big disc	AS/EN	100%
T-23.A.102-M	Thread Resistance - With smaller disc	AS/EN	100%
T-23.A.103-M	Thread Resistance - With buffer	AS/EN	100%
T-40.A.20-M	Casing design	AS	100%
T-40.A.21-M	Casing maintenance	AS	100%
T-40.A.22-M	Casing durability FEM	AS	100%
T-40.A.23-M	Fixing points	AS	100%

Design testing extends from mid of Jan to end of May because a final design can be delayed. Each test is therefore performed when the design of each module is ready.

MODULE TEST

After construction of the different modules, the project goes into module testing. Once a module is constructed, it can be tested by part of the group, while the other part can continue their work on the construction. This will result in a minimal amount of unused man-hours caused by waiting. The main purpose of this test phase is to ensure that everything works properly individually, and discovers bugs that occur when going from the ideal world to the real world. The amount of bugs caused by this should be minimized when the problem are in mind while designing the system. But there are certain problems that are hard to see in simulation, e.g. EMC (Electro Magnetic Compatibility), EMI (Electro Magnetic Interferes) and production deviation of mechanical parts. Like stated earlier, the main purpose of this testing is to test how the module behaves in a real world application. Later, all of the design tests are run again, but now on physical modules.

MECHANICAL MODULE TESTS

It is important to test some of the design tests on physical modules and see if the result matches. Some deviations stated from production can result in unacceptable results. Following qualities should be simulated and compared to design results.

- Operation speed
- Physical size
- Functionality
- Capacity

ELECTRICAL MODULE TESTS

- Temperature tolerance
- Operational voltage

Since this is the last individual test phase, the modules should work as intended before being moved to the integration test phase.

Table below is a summary of all module tests that shall be done. Each test number includes fields of status and test responsible. All test specifications can be found in "D-03.A.08-A" and test reports can be found in "D-03.A.20-A" document.

MODULE TESTING LIST

Test number:	Test description:	Assigned to:	Progress:
T-10.A.33-EM	Gripper height physical measure	VK	100%
T-10.A.35-EM	Gripper width physical measure	VK	100%
T-11.A.01-M	Gripper arm length physical measure	VK	100%
T-11.A.03-M	Gripper arm width physical measure	VK	100%
T-11.A.05-M	Gripper arm height physical measure	VK	100%
T-11.A.07-M	Gripper arm storage space physical measure	VK	100%
T-11.A.11-M	Gripper arm physical weight	VK	0%
T-12.A.84-M	Adjustment of free wheels physical measure	VK	100%
T-12.A.86-M	Feeding mechanism adjustment measure	VK	100%
T-12.A.96-EM	Stop/start point – ME060102	MSS	100%
T-12.A.87-EM	Travel speed – ME060102	MSS	100%
T-14.A.90-E	Voltage regulator specifications- L7812ACV	MSS	50%
T-14.A.92-E	Voltage follower specifications	MSS	100%
T-14.A.93-E	DAC specification – AD558	MSS	100%
T-14.A.98-E	Voltage amplifier specifications – CA3130	MSS	100%
T-20.A.36-EM	Thread selection speed	IYE/AV	0%
T-20.A.74-EM	Thread selection individual arm operation	IYE/AV	0%
T-20.A.75-EM	Position error	IYE/AV	100%
T-20.A.64-EM	Compatibility of different threads	IYE/AV	100%
T-20.A.65-EM	Capacity of managing multiple threads	IYE/AV	0%
T-21.A.45-EM	Thread cutter safety	AV/VK	0%
T-21.A.76-M	Thread cutter accuracy	AV/VK	0%
T-23.A.51-M	Thread holding system spool variation (adapters)	AS/EN	100%
T-30.A.54-E	Operational voltage	MSS	100%
T-30.A.89-E	Serial communication	IYE	100%
T-30.A.95-E	Analog comparator input voltages	EN	100%
T-31.A.62-E	Spool size	EN	100%
T-31.A.63-E	Door safety	EN/MSS	100%
T-31.A.66-E	Yarn sensor - Input voltage	EN	100%
T-31.A.67-E	Yarn sensor - Output voltage	EN	100%
T-40.A.71-M	Casing thickness	AS	100%
T-40.A.72-M	Chassis thickness	AS	100%
T-10.B.27-M	Replace gripper time	VK	100%
T-10.B.28-EM	Replace skills	VK	0%
T-23.B.88-EM	Thread holding system spool variation	AS/EN	100%

INTERGRATION TEST

The system is being assembled in the second construction iteration, and the construction activities can be seen in the document "Plan for second construction iteration" (D-01.A.29-A). New bugs may arise in the interaction between modules under the construction of the modules. The bugs may arise in the direct interaction and the indirect interaction (i.e. EMI) between modules. These tests should begin in a very small scale, i.e. just 2 modules tested with each other, and from there increase the numbers of modules connected to each other. This uncovers most of the interaction bugs.

Table below is a summary of all integration tests that shall be done. Each test number includes fields of status and test responsible. All test specifications can be found in "D-03.A.08-A" and test reports can be found in "D-03.A.20-A" document.

INTEGRATION TEST LIST

Test number:	Test description:	Assigned to:	Progress:
T-00.A.24-EM	Spool replacing skills	AS/EN	0%
T-11.A.82-M	Gripper arm Fixing points measure	VK	100%
T-12.A.17-EM	Stop/start point of the gripper arm	MSS	100%
T-12.A.18-E	Travel speed of the gripper and gripper arm	MSS	100%
T-22.A.47-EM	Thread feeding success	AS/EN	0%
T-22.A.94-E	Halt on multiple threads	AS/EN	100%
T-23.A.78-EM	Thread holding system arm brake	AS/EN	0%
T-40.A.73-M	System mounting	AS	100%
T-00.B.30-EM	Spool/thread replacement time	AS/EN	0%

FULL SYSTEM TEST

This phase can begin after all modules have been through module- and integration testing and the system is assembled. This phase can be divided into 2 parts, white box testing and black box testing.

WHITE BOX TESTING

White box testing is done by one or more of the project group members. This testing will mainly focus around

- Functionality
- Speed
- Security

The system will be tested without being mounted on the TC2 first, controlled by a computer. If this test is passed according to schedule, we might get the opportunity to test the system mounted on a TC2. If this opportunity arises, the test from above is repeated, but with more focus on functionality with the TC2.

BLACK BOX TESTING

Black box testing will be done by persons outside the project group. The "users" will get an introduction to how the system works, but no information about the system's inner workings. This might reveal undiscovered bugs that the group might not have been able to produce. Main focuses for this testing is:

- Functionality
- User-friendliness
- Operation
- Changing spools
- Cleaning

Table below is a summary of all full system tests that shall be done. Each test number includes fields of status and test responsible. All test specifications can be found in "D-03.A.08-A" and test reports can be found in "D-03.A.20-A" document.

FULL SYSTEM TESTING

Test number:	Test description:	Assigned to:	Progress:
T-00.A.25-E	Emergency button	MSS	50%
T-10.A.12-EM	Success rate	ALL	50%
T-11.A.09-M	Gripper arm lifetime		0%
T-21.A.43-EM	Thread cutter lifetime		0%
T-21.A.44-EM	Thread cutter lifetime sharpness		0%
T-22.A.46-EM	Thread feeding lifetime	AS/EN	0%
T-22.A.48-E	Thread feeding notify	AS/EN	100%
T-23.A.53-E	Notify that spools are becoming empty	AS/EN	100%
T-30.A.58-E	Emergency shutdown		0%
T-30.A.59-E	Communication		0%
T-30.A.60-E	Sleep time		0%
T-00.B.29-EM	System maintenance		0%
T-00.B.31-E	System reset after emergency shutdown		0%

TEST SPECIFICATIONS FOR THE "AUTOMATIC SHUTTLE CONTROL SYSTEM"

D-03.A.08-A

Release 3.0

TRONRUD ENGINEERING AS

RELEASE NOTES

Date	Version	Description	Author
30.12.2011	0.1	- first draft	Inge Ytre-Eide Andreas Stustad Eirik Nordstrand Vazgen Karlsen Andreas Vander
02.01.2012	0.1.1	- Added to term list	Inge Ytre-Eide
09.01.2012	0.2	- Added all tests	Andreas Vander Vazgen Karlsen
09.01.2012	0.3	-Corrected some spelling and changed format	Andreas Vander
09.01.2012	0.4	- Added T-20.A.64-EM and T-20.A.65-EM	Andreas Stustad
09.01.2012	1.0	- Finished document	Eirik Nordstrand
16.01.2012	1.0.1	- Removed term list	Inge Ytre-Eide
02.02.2012	1.1	- Added tests for yarn sensor.	Eirik Nordstrand
02.02.2012	1.2	-Added test for Thread Resistance #1 - Added test for Thread Resistance #1	Eirik Nordstrand
06.02.2012	1.3	- Added test T-22.A.70-M, T-40.A.71-M, T-40.A.72-M, T-40.A.73-M	Andreas Stustad
10.02.2012	1.3.1	- Added test for thread selection	Inge Ytre-Eide
23.02.2012	1.3.2	- Added test for Thread holding system	Eirik Nordstrand
27.02.2012	1.3.3	- Added test for Gripper arm and Feeding system.	Vazgen Karlsen
08.03.2012	1.3.4	- Edited T-23.A.51-M - Added T-23.B.88-EM	Andreas Stustad
14.03.2012	2.0	- Finalized document	Eirik Nordstrand
09.05.2012	2.1	- Edited T-22.A.70-M, T-23.A.50-M, T-40.A.22-M	Andreas Stustad
16.05.2012	2.2	- Spelling and grammar - Cross-checked tests to “list of used numbers” (module 14 test missing)	Andreas Stustad
16.05.2012	2.2.1	-Added pre written test specs (module 14) - Added test specs: T-12.A.17-EM, T-12.A.18-EM	Mats Strand Sætervik
21.05.2012	2.2.2	Edited T-00.B.30-EM,T-23.B.88-EM	Andreas Stustad

21.05.2012	2.2.3	Edited T-12.A.16-EM	Vazgen Karlsen
23.05.2012	2.2.4	Added T-30.A.95-E	Eirik Nordstrand
25.05.2012	2.3	Updated introduction	Mats Strand Sætervik
26.05.2012	2.4	Moved test for module 23 from test report to test spec	Eirik Nordstrand
29.05.2012	2.5	Removed: T-10.A.14-EM, T-00.A.26-E	Mats Strand Sætervik
29.05.2012	2.5.1	Added missing numbers for several tests.	Vazgen Karlsen
29.05.2012	3.0	Finalized document	Andreas Stustad

ABOUT THIS DOCUMENT

This document addresses the projects test strategy. It is divided into 4 phases:

- Design test
- Module test
- Integration test
- Full system test

In each phase, modules shall be tested in different scenarios. E.g. stress, compatibility. Also addressed in what manner the test shall be conducted. Every test is subjected to white-box testing. The only test phase that includes black box testing is the full system test.

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INTRODUCTION

The purpose with this document is to set the guidelines to how we`re going to run the tests and the goal of these tests.

- **Traceability test report:**
  This tells the reader in what document the test results can be found. Most of the test can be found Test report (T-03.A.-20-A)
- **By:**
  The group member who has written the test specification.
- **Date:**
  What date the specific test specification was last changed.
- **Traceability requirement:**
  What requirement this test is related to.
- **Test type:**
  What kind of test it is. This could for example be white box, black box, physical measurements, software test etc.
- **Requirement description:**
  The requirement specification which was earlier referred to.
- **Test description:**
  This will describe the test, what kind of component will be tested and how they will be tested.
- **Test execution:**
  This describes in detail how the test will be able to be approved or not approved. This could be an explanation of how a software test works or a description of electrical circuit.
- **Approval criteria:**
  What measurement that needs to be met to get an approved test.
- **Expected results:**
  This is what the person expects the test result to be. This could be equal to, better or worse than the approval criteria.
- **Possible errors:**
  This is errors the tester could expect to encounter. These errors could result in an incomplete/not approved test.

A-TESTS

THE ENTIRE SYSTEM

T-00.A.24-EM SPOOL REPLACING SKILLS		
Traceability test report:	**By:** VK	**Date:** 06.01.2012
Traceability requirement: R-00.A.39-EM	**Test type:** Prototype test	
Requirement description: Changing the spool and laying the new threads should not require any technical knowledge.		
TEST		
Test description: Persons outside the group will perform the test.		
Test execution: The user will get an introduction to how the system works. The user will try to change the spool and lay a new thread.		
Test equipment: Prototype of ASCS-module, spools.		
Approval criteria: Users are able to change spools and lay new threads without any problems.		
Expected results: Users are able to change spools and lay new threads without any problems.		
Possible errors: Unable to finish the prototype module.		

T-00.A.25-E EMERGENCY BUTTON		
Traceability test report: D-03.A.20-A	**By:** VK	**Date:** 06.01.2012
Traceability requirement: R-00.A.13-E	**Test type:** Prototype test	
Requirement description: When the emergency button is pushed, the system shall halt at once.		
TEST		
Test description: An emergency button (or a button which can be replaced with an emergency button) will be pressed.		
Test execution: First of all the system is started, and then when the system is running the button will be pushed.		
Test equipment: Prototype of ASCS-module		
Approval criteria: When the emergency button is pushed, the system stops at once. The software has to be notified that emergency button has been pressed and halts the system and the switch also needs to cut power to the feeding mechanism motor.		
Expected results: When the emergency button is pushed, the system stops at once.		
Possible errors: Unable to finish the prototype module.		

GRIPPER

T-10.A.12-EM SUCCESS RATE

Traceability test report: D-03.A.20-A	**By:** VK	**Date:** 04.01.2012
Traceability requirement: R-10.A.00-EM	**Test type:** Full system test	
Requirement description: The gripper shall never fail to grab thread more than 1 out of 1000 cycles, i.e. 1‰		
TEST		
Test description: The feeding mechanism is set to 10 000 cycles with failure log.		
Test execution: The feeding mechanism runs 10 000 cycles while the tester/testers watches the test and observes what kind of errors occurs that might corrupt the success rate.		
Test equipment: Module prototype, thread spool, monitoring equipment.		
Approval criteria: The gripper fails less than 10 out of 10 000 cycles.		
Expected results: The gripper fails to grab the thread more than 10 out of 10 000 cycles		
Possible errors: Power loss or one of the modules fails.		

T-10.A.13-M LIFETIME

Traceability test report:	**By:** VK	**Date:** 04.01.2012
Traceability requirement: R-10.A.01-M	**Test type:** FEM analysis	
Requirement description: The gripper should have a lifetime of at least 1 year or 1875 working hours.		
TEST		
Test description: Fatigue analysis by using Finite element method.		
Test execution: Make a fatigue analysis for the gripper by using Solidworks simulation with cycles equivalent to 1750 working hours.		
Test equipment: Solidworks CAD software, Solidworks simulation software, Computer, CAD files of ASCS-module.		
Approval criteria: None of the gripper parts fails.		
Expected results: One or multiple parts fail.		
Possible errors: Computer crash, power loss		

T-10.A.32-EM GRIPPER HEIGHT SW

Traceability test report:	**By:** VK	**Date:** 09.01.2012
Traceability requirement: R-10.A.54-EM	**Test type:** Solidworks measure	
Requirement description: The height of the gripper shall be far less than 19,2mm		
TEST		
Test description: The height of the gripper is measured.		
Test execution: One of the group members measures the height of the gripper by using a Solidworks.		
Test equipment: Solidworks, Computer, CAD drawings of ASCS-module.		
Approval criteria: The height of the gripper is far less than 19,2mm		
Expected results: The height of the gripper is measured with Solidworks measurement tool to be less than 19,2mm.		
Possible errors: Computer crash, power loss.		

T-10.A.33-EM GRIPPER HEIGHT

Traceability test report:	**By:** VK	**Date:** 09.01.2012
Traceability requirement:R-10.A.54-EM	**Test type:** Measure test	
Requirement description: The height of the gripper shall be far less than 19,2mm		
TEST		
Test description: The height of the gripper is measured.		
Test execution: One of the group members measures the height of the gripper by using a caliper.		
Test equipment: Caliper, gripper.		
Approval criteria: The height of the gripper is far less than 19,2mm		
Expected results: The height of the gripper is measured by caliper to be less than 19,2mm		
Possible errors: Unable to finish the prototype module.		

T-10.A.34-EM GRIPPER WIDTH SW		
Traceability test report:	**By:**	**Date:**
Traceability requirement: R-10.A.55-EM	**Test type:** Solidworks measure	
Requirement description: The width of the gripper shall be far less than 157,3mm / 2 = 78,5mm This is half of the shed width.		
TEST		
Test description: The width of the gripper is measured.		
Test execution: One of the group members measures the height of the gripper by using a Solidworks.		
Test equipment: Solidworks, Computer, CAD drawings of ASCS-module.		
Approval criteria: The width of the gripper is less than 78,5mm		
Expected results: The width of the gripper is measured by Solidworks measurement tool to be less than 78,5mm.		
Possible errors: Computer crash, power loss.		

T-10.A.35-EM GRIPPER WIDTH		
Traceability test report:	**By:**	**Date:**
Traceability requirement: R-10.A.55-EM	**Test type:** Measure test	
Requirement description: The width of the gripper shall be far less than 157,3mm / 2 = 78,5mm This is half of the shed width.		
TEST		
Test description: The width of the gripper is measured.		
Test execution: One of the group members measures the width of the gripper by using a caliper.		
Test equipment: Caliper, gripper.		
Approval criteria: The width of the gripper is less than 78,5mm		
Expected results: By a caliper the width of the gripper is measured to be less than 78,5mm.		
Possible errors: Unable to finish the prototype module.		

GRIPPERARM

T-11.A.00-M GRIPPER ARM LENGTH SW

Traceability test report:	**By:** Andreas Stustad	**Date:** 04.01.2012
Traceability requirement: R-11.A.06-M	**Test type:** Solidworks measure	
Requirement description: Gripper arm length shall be at least 1000mm		
TEST		
Test description: Make sure that the gripper arm is long enough to pick up a thread. This means that the gripper arm must be at least 1m long to cover the whole width of the TC2		
Test execution: The length of the gripper arm are measured		
Test equipment: Measuring tool in Solidworks		
Approval criteria: The gripper arm is longer than 1000mm		
Expected results: The gripper arm is measured by Solidworks measurement tool to be longer than 1000mm.		
Possible errors: If the gripper arm is shorter than 1m, it is a possibility that it is too short to be able to pick up a thread		

T-11.A.01-M GRIPPER ARM LENGTH

Traceability test report:	**By:** Andreas Stustad	**Date:** 04.01.2012
Traceability requirement: R-11.A.06-M	**Test type:** Physical measurement	
Requirement description: Gripper arm length shall be at least 1000mm		
TEST		
Test description: Make sure that the gripper arm is long enough to pick up a thread. This means that the gripper arm must be at least 1m long to cover the whole width of the TC2		
Test execution: The length of the gripper arm are measured		
Test equipment: Measuring tape		
Approval criteria: The gripper arm is longer than 1000mm		
Expected results: The gripper arm is measured by a caliper to be longer than 1000 mm.		
Possible errors: If the gripper arm is shorter than 1m, it is a possibility that it is too short to be able to pick up a thread		

T-11.A.02-M GRIPPER ARM WIDTH SW		
Traceability test report:	**By:** Andreas Stustad	**Date:** 04.01.2012
Traceability requirement:R-11.A.27-M	**Test type:** Solidworks measure	
Requirement description: Gripper arm shall be far less than 125,8mm in width		
TEST		
Test description: Make sure that the gripper arm is less than 125,8mm in width. This is to make sure that the gripper arm does not catch the warp threads.		
Test execution: The width of the gripper arm is measured.		
Test equipment: Solidworks measuring tool		
Approval criteria: The gripper arm width is smaller than 125,8mm		
Expected results: The gripper arm width is measured by Solidworks measurement tool to be smaller than 125,8mm.		
Possible errors: If the gripper arm is wider, it is a possibility that the gripper arm catches the warp threads		

T-11.A.03-M GRIPPER ARM WIDTH		
Traceability test report:	**By:** Andreas Stustad	**Date:** 04.01.2012
Traceability requirement:R-11.A.27-M	**Test type:** Physical measurement	
Requirement description: Gripper arm shall be far less than 125,8mm in width		
TEST		
Test description: Make sure that the gripper arm is less than 125,8mm in width. This is to make sure that the gripper arm does not catch the warp threads.		
Test execution: The width of the gripper arm is measured.		
Test equipment: Slide gauge		
Approval criteria: The gripper arm width is smaller than 125,8mm		
Expected results: By using a caliper the gripper arm width is measured to be smaller than 125,8mm.		
Possible errors: If the gripper arm is wider, it is a possibility that the gripper arm catches the warp threads		

T-11.A.04-M GRIPPER ARM HEIGHT SW		
Traceability test report:	**By:** Andreas Stustad	**Date:** 04.01.2012
Traceability requirement:R-11.A.35-M	**Test type:** Solidworks measure	
Requirement description: The height of the gripper arm shall be less than 19,2mm		
TEST		
Test description: Make sure that the gripper arm height is shorter than 19,2mm. This is to make sure that the gripper arm do not catch the warp threads		
Test execution: The height of the gripper arm is measured.		
Test equipment: Solidworks measuring tool		
Approval criteria: The gripper arm height is less than 19,2mm		
Expected results: The gripper arm height is measured by Solidworks measurement tool to be less than 19,2mm.		
Possible errors: If the gripper arm is taller, it is a possibility that it can catch the warp threads		

T-11.A.05-M GRIPPER ARM HEIGHT		
Traceability test report:	**By:** Andreas Stustad	**Date:** 04.01.2012
Traceability requirement:R-11.A.35-M	**Test type:** physical measurement	
Requirement description: The height of the gripper arm shall be less than 19,2mm		
TEST		
Test description: Make sure that the gripper arm height is shorter than 19,2mm. This is to make sure that the gripper arm do not catch the warp threads		
Test execution: The height of the gripper arm is measured.		
Test equipment: Slide gauge		
Approval criteria: The gripper arm height is less than 19,2mm		
Expected results: By using caliper the gripper arm height is measured to be less than 19,2mm.		
Possible errors: If the gripper arm is taller, it is a possibility that it can catch the warp threads		

T-11.A.06-M GRIPPER ARM STORAGE SPACE SW		
Traceability test report:	**By:** Andreas Stustad	**Date:** 04.01.2012
Traceability requirement: R-11.A.07-M	**Test type:** Solidworks measure	
Requirement description: Gripper arm storage space		
TEST		
Test description: Make sure that the gripper arm can be stored in the system module		
Test execution: Test if the gripper arm can be stored in the module with the other components		
Test equipment: Solidworks assembly		
Approval criteria: The gripper arm can be stored without interfere with other components		
Expected results: The gripper arm catches or stands in the way of other components.		
Possible errors: The gripperarm catches or stand in the way of other components		

T-11.A.07-M GRIPPER ARM STORAGE SPACE		
Traceability test report:	**By:** Andreas Stustad	**Date:** 04.01.2012
Traceability requirement:R-11.A.07-M	**Test type:** Module/prototype	
Requirement description: Gripper arm storage space		
TEST		
Test description: Make sure that the gripper arm can be stored in the system module		
Test execution: Test if the gripper arm can be stored in the module with the other components		
Test equipment: Mock-up module, TC2		
Approval criteria: The gripper arm can be stored without interfere with other components		
Expected results: The gripper arm catches or stands in the way of other components.		
Possible errors: The gripper arm catches or stand in the way of other components		

T-11.A.08-M GRIPPER ARM LIFETIME SW		
Traceability test report:	**By:** Andreas Stustad	**Date:** 04.01.2012
Traceability requirement:R-11.A.08-M	**Test type:** FEM fatigue	
Requirement description: Gripper arm lifetime of 13.125.00 cycles		
TEST		
Test description: Make sure that the gripper arm can handle the variable loads and stresses that occur in simulated operation		
Test execution: Use Finite element method to calculate if the gripper arm handles 13.125.000 cycles		
Test equipment: Solidworks Simulation		
Approval criteria: The gripper arm handles 13.125.000 cycles · 2		
Expected results: The gripper arm fails to survive		
Possible errors: The gripperarm is designed too fragile		

T-11.A.09-M GRIPPER ARM LIFETIME		
Traceability test report:	**By:** Andreas Stustad	**Date:** 04.01.2012
Traceability requirement:R-11.A.08-M	**Test type:** Module/prototype	
Requirement description: Gripper arm lifetime of 13.125.000 cycles		
TEST		
Test description: Make sure that the gripper arm can handle the variable loads and stresses that occur in operation		
Test execution: Test the gripper arm function in operation for at least 13.125.000 cycles		
Test equipment: mock-up TC2, mock-up module with gripper arm		
Approval criteria: The gripper arm handles all the cycles		
Expected results: The gripper arm fails to survive		
Possible errors: The gripperarm is designed too fragile		

T-11.A.11-M GRIPPER ARM WEIGHT		
Traceability test report:	**By:** Andreas Stustad	**Date:** 04.01.2012
Traceability requirement: R-11.A.09-M	**Test type:** Module/prototype	
Requirement description: The gripper arm must be so light that it does not affects the rest of the system i.e. electrical motors or warps.		
TEST		
Test description: Test if the gripper arm does not affects the rest of the system.		
Test execution: Test the gripper arm on the module.		
Test equipment: Module, gripper arm		
Approval criteria: The gripper arm does not affects the rest of the system in any way		
Expected results: The gripper arm is too heavy		
Possible errors: The gripper is too heavy designed, and can be too heavy for the servos		

T-11.A.79-M GRIPPER ARM STRENGTH FEM		
Traceability test report:	**By:** VK	**Date:** 02.02.2012
Traceability requirement: R-11.A.69-M	**Test type:** FEM analysis	
Requirement description: The gripper arm shall withstand the bend stresses that occur.		
TEST		
Test description: Stress and bend analysis by using Solid works simulation.		
Test execution: Make a stress analysis with a force that act on the gripper arm by acceleration.		
Test equipment: Computer, Solid works software and Cad drawings.		
Approval criteria: Gripper arm withstands the stresses that occur.		
Expected results: Gripper arm withstands the stresses that occur.		
Possible errors: Computer crash		

T-11.A.80-M GRIPPER ARM CROSS SECTION		
Traceability test report:	**By:** VK	**Date:** 02.02.2012
Traceability requirement: R-11.A.70-M	**Test type:** Solid works measure	
Requirement description: Cross section of the gripper arm shall be 2.5mm*0,2mm with 14.4mm as radius.		
TEST		
Test description: The gripper arm is measured by using Solid works.		
Test execution: Measure the gripper arm by using measure toll in Solid works.		
Test equipment: Computer, Solid works software and Cad drawings.		
Approval criteria: Cross section of the gripper arm is 2,5mm $*$ 0,2mm with 14.4mm as radius.		
Expected results: Cross section of the gripper arm is measured by Solidworks measurement tool to be 2,5mm $*$ 0.2mm with 14.4mm as radius.		
Possible errors: Computer crash		

T-11.A.81-M GRIPPER ARM FIXING POINTS MEASURE (SW)		
Traceability test report:	**By:** VK	**Date:** 02.02.2012
Traceability requirement: R-11.A.71-M	**Test type:** Solid works measure	
Requirement description: The gripper arm shall contain fixing points that matches fixing points for the gripper and feeding mechanism.		
TEST		
Test description: Fixing points are measured in Solid works		
Test execution: Fixing points are measured with measure tool in Solid works		
Test equipment: Computer, Solid works software and Cad drawings.		
Approval criteria: Fixing points matches each other.		
Expected results: Fixing points matches each other.		
Possible errors: Computer crash		

T-11.A.82-M GRIPPER ARM FIXING POINTS MEASURE		
Traceability test report:	**By:** VK	**Date:** 02.02.2012
Traceability requirement: R-11.A.71-M	**Test type:** Physical measurement	
Requirement description: The gripper arm shall contain fixing points that match fixing points for the gripper.		
TEST		
Test description: Make sure that the fixing points of the gripper arm matches the fixing points of the gripper. The fixing points are measured by a calliper.		
Test execution: One of the group members measures the fixing points		
Test equipment: Calliper		
Approval criteria: Fixing points matches each other.		
Expected results: Fixing points matches each other.		
Possible errors: Measure inaccuracy, Missing prototype parts.		

T-12.A.16-EM LIFETIME

Traceability test report:	**By:** VK	**Date:** 04.01.2012
Traceability requirement: R-12.A.10-EM	**Test type:** FEM analysis	

Requirement description: The feeding mechanism should have a lifetime of at least 1 year or 1875 working hours.

Calculation of cycles per lifetime:

25 cycles/min · 60min =1500 cycles/hour.

1875 working hours · 1500 cycles/hour = 2 812 500 cycles.

TEST

Test description: Fatigue analysis by using Finite element method.

Test execution: Make a fatigue analysis for most exposed part of the feeding mechanism for gripper arm by using Solidworks simulation with2 812 500 cycles.

Test equipment: Solidworks CAD software, Solidworks simulation software, Computer, CAD files of ASCS-module.

Approval criteria: None of the feeding mechanism parts fails.

Expected results: None of the feeding mechanism parts fails.

Possible errors: Computer crash, power loss.

T-12.A.17-E STOP/START POINT - WITH FEEDING MECHANISM

Traceability test report: Test report (D-03.A.08-A)	**By:** MSS	**Date:** 04.01.2012
Traceability requirement: R-12.B.75-EM	**Test type:** Physical measurements	

Requirement description: The feeding mechanism has to start and stop the gripper arm at the same point each cycle. An acceptable error is defined by +/- 5 mm in relation to the start/stop point.
The endpoint is defined as 5 mm behind the thread at pickup, and 5 mm in front of the pulley wheel at the start point.

TEST

Test description: Complete test with gripper, gripper arm and feeding mechanism. Measure if the gripper stops within +-/ 5 mm at the endpoint. The ME060102 was connected to the feeding mechanism, illustrated in Figure 1.

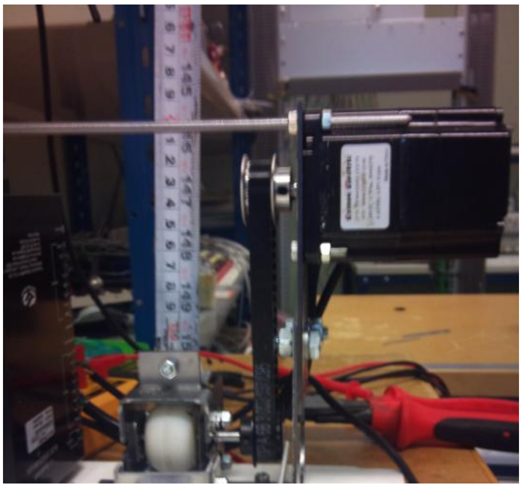

Figure 1: ME060102, with feeding mechanism

Test execution: Running continuous cycles, measuring the error at the endpoint.

Test equipment: ATmega128RFA1, Gripper, feeding mechanism and gripper arm

Approval criteria: The gripper stops within +/- 5 mm each cycle.

Expected results: The gripper stops within +/- 5 mm each cycle.

Possible errors: Computer crash, power loss, less accuracy is achieved

T-12.A.18-EM TRAVEL SPEED - WITH FEEDINGMECHANISM

Traceability test report: Test report (D-03.A.08-A)	**By:** MSS	**Date:** 04.01.2012
Traceability requirement:R-12.A.77-EM	**Test type:** Module and integration tests	
Requirement description: The feeding mechanism has to propel the gripper and gripper arm across the shed and back again within 1 second. The acceleration and top speed has to be calculated accordingly to meet this requirement.		
TEST		
Test description: Complete test with gripper, gripper arm and feeding mechanism. Measure how long time one cycle takes.		
Test execution: Running several cycles, measure average travel time.		
Test equipment: ATmega128RFA1, Gripper, feeding mechanism and gripper arm		
Approval criteria: The average travel time for one cycle is < 1 second.		
Expected results: The average travel time for one cycle is < 1 second.		
Possible errors: Computer crash, power loss, less speed is achieved		

T-12.A.96-EM STOP/START POINT – ME060102

Traceability test report: Test report (D-03.A.08-A)	**By:** MSS	**Date:** 03.04.2012
Traceability requirement: R-12.B.75-EM	**Test type:** Physical measurements	

Requirement description: The feeding mechanism has to start and stop the gripper arm at the same point each cycle. An acceptable error is defined by +/- 5 mm in relation to the start/stop point.
The endpoint is defined as 5 mm behind the thread at pickup, and 5 mm in front of the pulley wheel at the start point.

TEST

Test description: Test of the control algorithm together with the motor, ME060102.

Test execution: The ME060102 will be used with no load, the goal is to see if the motor can run continuously and return to the same point at the end of each cycle. The motor shaft will be marked with a colored line or dot as illustrated in Figure 2.

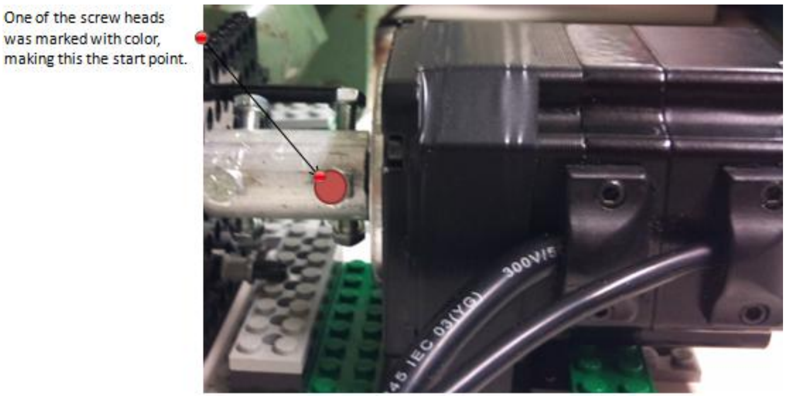

Figure 2: ME060102, without load

The NI USB-6008 will be used as a DAC

Test equipment: ATmega128RFA1, ME060102, NI-USB 6008

Approval criteria: The gripper stops within +/- 5 mm each cycle.

Expected results: The gripper stops within +/- 5 mm each cycle.

Possible errors: Computer crash, power loss, troubles with NI-UBS 6008, algorithm errors resulting in less accuracy.

T-12.A.97-EM TRAVEL SPEED- ME060102		
Traceability test report: Test report (D-03.A.08-A)	**By:** MSS	**Date:** 05.04.2012
Traceability requirement:R-12.C.77-EM	**Test type:** Physical measurement	
Requirement description: The feeding mechanism has to propel the gripper and gripper arm across the shed and back again within 1 second. The acceleration and top speed has to be calculated accordingly to meet this requirement.		
TEST		
Test description: Test of the control algorithm together with the motor, ME060102. Measure how long one cycle takes, the motor won't be connected to any load.		
Test execution: Running several cycles, measure average travel time.		
Test equipment: ATmega128RFA1, ME060102, NI-USB 6008, stop watch		
Approval criteria: The average travel time for one cycle is < 1 second.		
Expected results: The average travel time for one cycle is more than 1 second.		
Possible errors: Computer crash, power loss, less speed is achieved		

T-12.A.19-M STRENGTH		
Traceability test report:	**By:** VK	**Date:** 04.01.2012
Traceability requirement:R-12.A.53-M	**Test type:** FEM analysis	
Requirement description: The feeding mechanism for the gripper arm shall withstand the stresses that occurs when the system stops suddenly or power loss.		
TEST		
Test description: Make a stress analysis by using Finite element method.		
Test execution: Calculate the load that occurs when the feeding system stops at maximum speed and plug it into stress analysis.		
Test equipment: Solidworks CAD software, Solidworks simulation software, Computer, CAD files of ASCS-module.		
Approval criteria: The feeding system withstands the stresses that occur when the system stops.		
Expected results: The feeding system withstands the stresses that occur when the system stops.		
Possible errors: Computer crash, power loss.		

T-12.A.83-M ADJUSTMENT OF FREE WHEELS MEASURE (SW)		
Traceability test report:	**By:** VK	**Date:** 02.02.2012
Traceability requirement: R-12.A.72-M	**Test type:** Solid works measure	
Requirement description: Free wheels (support wheels) around pulley wheel for the gripper arm shall be adjustable in the direction of pulley wheels centre. Adjustable range of minimum 3mm.		
TEST		
Test description: Adjustable range for free wheels is measured in Solidworks.		
Test execution: Fixing points are measured with measure tool in Solidworks		
Test equipment: Computer, Solid works software and Cad drawings.		
Approval criteria: Adjustable range of free wheels is at least 3 mm.		
Expected results: Aadjustable range of free wheels is at least 3 mm.		
Possible errors: Computer crash		

T-12.A.84-M ADJUSTMENT OF FREE WHEELS MEASURE		
Traceability test report:	**By:** VK	**Date:** 02.02.2012
Traceability requirement: R-12.A.72-M	**Test type:** Measure	
Requirement description: Free wheels (support wheels) around pulley wheel for the gripper arm shall be adjustable in the direction of pulley wheels centre. Adjustable range of minimum 3mm.		
TEST		
Test description: Adjustable range is measured by a calliper.		
Test execution: One or several group member's measures adjustable range of the free wheels.		
Test equipment: Prototype parts and calliper.		
Approval criteria: Adjustable range of free wheels is at least 3 mm.		
Expected results: Adjustable range of free wheels is at least 3 mm.		
Possible errors: Missing prototype parts.		

T-12.A.85-M FEEDING MECHANISM ADJUSTMENT MEASURE (SW)		
Traceability test report:	**By:** VK	**Date:** 02.02.2012
Traceability requirement: R-12.A.73-M	**Test type:** Solidworks measure	
Requirement description: The whole feeding mechanism shall be adjustable in x, y and z direction. Adjustable range of minimum 10 mm in each direction.		
TEST		
Test description: Adjustable range is measured by using measure tool in Solidworks.		
Test execution: One or several group member's measures adjustable range of the whole feeding mechanism.		
Test equipment: Computer, Solid works software and Cad drawings.		
Approval criteria: Adjustable range of the feeding mechanism is at least 10 mm.		
Expected results: Adjustable range of the feeding mechanism is at least 10 mm.		
Possible errors: Computer crash, missing Cad drawings.		

T-12.A.86-M ADJUSTMENT OF FREE WHEELS MEASURE		
Traceability test report:	**By:** VK	**Date:** 02.02.2012
Traceability requirement: R-12.A.73-M	**Test type:** Measure	
Requirement description: The whole feeding mechanism shall be adjustable in x, y and z direction. Adjustable range of minimum 10 mm in each direction.		
TEST		
Test description: Adjustable range is measured by a calliper.		
Test execution: One or several group member's measures adjustable range of the feeding system.		
Test equipment: Prototype parts, calliper.		
Approval criteria: Adjustable range of the feeding mechanism is at least 10 mm.		
Expected results: Adjustable range of the feeding mechanism is at least 10 mm.		
Possible errors: Missing prototype parts.		

T-14.A.90-E VOLTAGE REGULATOR SPECIFICATIONS - L7812ACV

Traceability test report: D-03.A.20-A	**By:** MSS	**Date:** 04.05.2012
Traceability requirement: R-14.A.78-E	**Test type:** Physical measurement	
Requirement description: The following specification needs to be satisfied: - Voltage in : 24 V +/- 0,5 V - Voltage out: 12 V +/-0,3 V - The voltage regulator have to be able to deliver 0,4 A.		
TEST		
Test description: Make sure the voltage regulator can deliver the specified voltages and currents		
Test execution: Construct the circuit on breadboard and read voltages, ensure that the component works. A variable effect resistor will be used as load, the resistor has a range of 0-100 Ohm.		
Test equipment: Fluke 45, Power supply 24 V, effect resistor, L7812ACV, breadboard		
Approval criteria: The voltage regulator delivers 12 V output with a supply of 24 V with load that draws 0,4 A		
Expected results: The regulator will deliver 12 V and function on 24 V supply and manage to deliver 0.4 Ampere without getting overheated.		
Possible errors: Mail functional hardware can give different voltages, wrong calculations may result in higher or lower output currents, heat problems causing the regulator to drop its output voltage.		

T-14.A.92-E VOLTAGE FOLLOWER SPECIFICATION- CA3130		
Traceability test report: D-03.A.20-A	**By:** MSS	**Date:** 30.04.2012
Traceability requirement: R-14.A.81-E	**Test type:** Physical measurement	

Requirement description: The following specification needs to be satisfied:

- Got to operate on voltage supply 12 V +/- 1 Volts
- The operational amplifier has to support rail to rail output.
- The voltage output has to match the voltage the non inverting input, with a maximum error of +/- 0,1 V

TEST

Test description: Make sure the voltage follower hold the voltage set to the non-inverting input, while VCC + is 12 Volts and Vcc- is ground.

Test execution: Construct the circuit on breadboard and read voltages, using the same components used in the test circuit found in the datasheet, making a similar circuit.

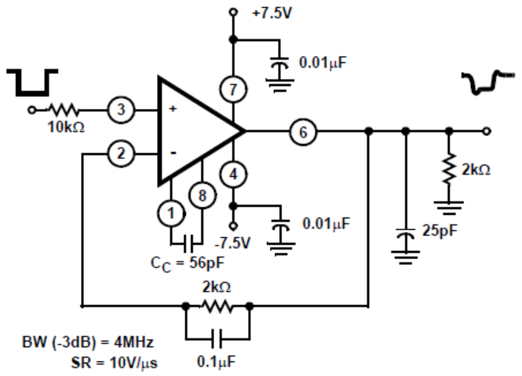

Figure 3: Test circuit, voltage follower, open loop[1]

For our test we don't plan to use a negative voltage supply or the 10 kOhm resistance shown connected to the non-inverting input in Figure 3. The electrolyte capacitors will also be replaced regular capacitors.

The non inverting input range will be from 0 -5 V ,the test will start at 0 V and increment in steps of 0,2 V up to 5 V.

Test equipment: Fluke 45, power supply, CA3130

Approval criteria: The voltage reference delivers the same voltage as the input on the non-inverting input V with voltage supply at 12 V.

Expected results: The voltage output is the same as the voltage input on the inverting input.

Possible errors: Mail functional hardware can give different voltages or the op amp isn't rail to rail and can't deliver approximately 0 V.

T-14.A.93-E DAC SPECIFICATIONS- AD558		
Traceability test report: D-03.A.20-A	**By:** MSS	**Date:** 30.04.2012
Traceability requirement: R-14.A.83-E	**Test type:** Physical measurement	
Requirement description: The following specification needs to be satisfied: - The DAC have to be a 8 bit parallel DAC - Got to operate on voltage supply 12 V +/- 1 Volts - The DAC have to deliver a voltage output in the range of 0 -5 V +/- 0.1 Volt.		
TEST		
Test description: Make sure the DAC delivers the specified output voltage when different bit values are set. Input bit from LSB(Least significant bit) to MSB(Most significant bit) have to be toggled to check if the output voltage changes		
Test execution: Construct the circuit on breadboard and read voltages, ensure that the component works. Use NI-USB test software to set the LSB to MSB.		
Test equipment: Fluke 45, power supply, voltage regulator, voltage follower, voltage reference and NI-USB 6008.		
Approval criteria: The voltage toggles from 0 – 5 volt when LSB to MSB are changed.		
Expected results: The voltage toggles from 0 – 5 volt when LSB to MSB are changed.		
Possible errors: Mail functional hardware can give different voltages wrongly and wrongly constructed circuit may cause faults.		

T-14.A.98-E	VOLTAGE AMPLIFIER SPECIFIACTION – CA3130	
Traceability test report: D-03.A.20-A	**By:** MSS	**Date:** 30.04.2012
Traceability requirement: R-14.A.83-E	**Test type:** Physical measurement	

Requirement description: The amplifier specification needs to be satisfied:

- Got to operate on voltage supply 12 V +/- 1 Volts
- The operational amplifier has to support rail to rail output.
- The output voltage has to change as fast as or faster than the output voltage of DAC.
- The gain of the amplifier has to be $\frac{4,6\ V}{2,56\ V}$ = 1,8 +/- 0,1

TEST

Test description: Measure the voltage amplifier output voltage, while VCC + is 12 Volts and Vcc- is ground.

Test execution: Construct the circuit on breadboard and read voltages, using the same components used in the test circuit found in the datasheet, making a similar circuit.

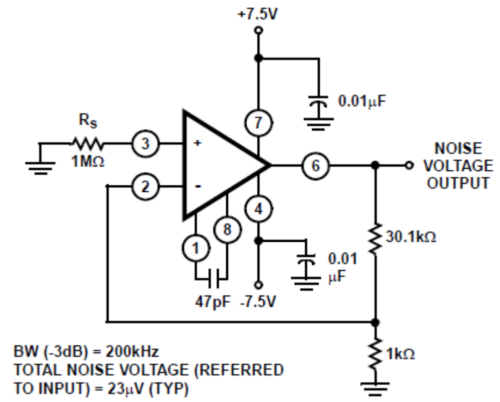

FIGURE 7. TEST-CIRCUIT AMPLIFIER (30-dB GAIN) USED FOR WIDEBAND NOISE MEASUREMENTS

Figure 4: Test circuit, close loop amplifier[1]

The test circuit found in the datasheet is illustrated in Figure 4. In our test circuit the 1 kOhm resistor is going to be replaced with a 1.2 MOhm resistance and the 30.1 kOhm with a 1 MOhm resistance.

The test will be don e by setting the non inverting input to 0 and 2.56 V. Checking the output at these voltage inputs.

Test equipment: Fluke 45, power supply, CA3130

Approval criteria: The non inverting input voltage is gained by 1,8 +/ 0,1

Expected results: The non inverting input voltage is gained by 1,8 +/ 0,1

Possible errors: Mail functional hardware can give different voltages wrongly constructed circuit may cause faults.

THREAD SELECTION

T-20.A.36-EM SPEED		
Traceability test report:	By: Andreas Vander	Date: 04.01.2012
Traceability requirement: R-20.A.14-EM	**Test type:** Module testing	
Requirement description: The next thread must be ready before the gripper arm comes to pick it up**.**		
TEST		
Test description: Test the module if the thread is ready**.**		
Test execution: Integrated test with whole system.		
Test equipment: ASCS-module prototype		
Approval criteria: Thread is ready		
Expected results: Thread is ready		
Possible errors: Thread is not ready and does not get picked up**.**		

T-20.A.40-EM LIFETIME		
Traceability test report:	**By:** Andreas Vander	**Date:** 04.01.2012
Traceability requirement: R-20.A.18-EM	**Test type:** Fatigue test	
Requirement description: The thread selection system shall have a lifetime of at least 5 years.		
TEST		
Test description: Fatigue analysis with FEM (Finite element analysis)		
Test execution: Use Solidworks simulation to fatigue tests the part(s) which is subjected to the highest number of cycles and load for 5 years or 9375 working hours.		
Test equipment: PC with Solidworks simulation		
Approval criteria: The thread selection system does not fail		
Expected results:		
Possible errors: The thread selection system fails before 9375 working hours.		

T-20.A.74-EM INDIVIDUAL OPERATION		
Traceability test report:	**By:** Inge Ytre-Eide	**Date:** 10.02.2012
Traceability requirement: R-20.A.64-EM	**Test type:** Module/prototype	
Requirement description: The arms on the thread selection shall operate individually so the gripper doesn't hit any other threads/parts		
TEST		
Test description: Test movement on the arms		
Test execution: Run arms in random order, check for movement on other arms and check for disturbances in the other arms hardware		
Test equipment: Threads, module, oscilloscope		
Approval criteria: Arms not in use, shall not be reaction on other signals/disturbances		
Expected results: Some spikes in control system for the module, but can probably be avoided with shielding		
Possible errors: EMC		

T-20.A.75-EM POSITION ERROR		
Traceability test report:	**By:** Inge Ytre-Eide	**Date:** 10.02.2012
Traceability requirement: R-20.A.65-EM	**Test type:** Module/prototype	
Requirement description: The operation arm shall place the thread so that the gripper can pick it up		
TEST		
Test description: Test movement on the arms		
Test execution: Run arms in random order, check movement on other arms, length and position when gripper come to pick the thread up		
Test equipment: Threads, module, paper & pen, ruler		
Approval criteria: The arms moves to the same positions each time, with a minimal error		
Expected results: The arms moves as planned		
Possible errors: Slipping in the movement mechanism, motor control failure		

T-20.A.64-EM COMPABILITY		
Traceability test report:	**By:** AS/AV	**Date:** 09.01.2012
Traceability requirement: R-20.A.17-EM	**Test type:** Full system test	
Requirement description: The system will be able to handle all types of threads as can be used on the TC2.		
TEST		
Test description: Test if the selection system can handle all kinds of threads.		
Test execution: Do a full system test to see if the thread selection is able to handle all kind of different threads.		
Test equipment: Prototype		
Approval criteria: The selection system can handle all kinds of threads without problems.		
Expected results: It will be able to handle all kind of different threads.		
Possible errors: Friction and breaking strength from different types of threads.		

T-20.A.65-EM CAPACITY		
Traceability test report:	**By:** Andreas Stustad	**Date:** 09.01.2012
Traceability requirement: R-20.A.16-EM	**Test type:** Module/prototype	
Requirement description: The system must be able to manage at least 8 different threads		
TEST		
Test description: Test if the thread selection system can handle 8 different threads.		
Test execution: Test the module/prototype with 8 threads and make sure it works well		
Test equipment: Threads, module		
Approval criteria: The thread selection system can handle 8 threads		
Expected results: It fails because the threads makes mess		
Possible errors: The threads are not delivered properly.		

T-20.A.77-EM SIZE		
Traceability test report:	**By:** IYE & AV	**Date:** 10.02.2012
Traceability requirement: R-20.A.67-EM	**Test type:** Module/prototype	
Requirement description: The module size should not exceed the limitations given by Tronrud Engineering		
TEST		
Test description: Check the CAD sizes		
Test execution: Control the measurements in the CAD`s in Solidworks		
Test equipment: CAD`s		
Approval criteria: The thread selection system fits in the designated area		
Expected results: The system fits		
Possible errors: The module is oversized and/or has a faulty design		

T-21.A.42-EM THREAD CUTTER LIFETIME SW		
Traceability test report:	**By:** Andreas Stustad	**Date:** 05.01.2012
Traceability requirement: R-21.A.22-EM	**Test type:** FEM fatigue	
Requirement description: The thread cutting system should have a lifetime of 2.625.000 cycles		
TEST		
Test description: Make sure that the thread cutting system can handle the variable loads and stresses that occur under simulated operation.		
Test execution: Use Finite element method to calculate if the thread cutter handles 2.625.000 cycles		
Test equipment: Solidworks Simulation		
Approval criteria: The thread cutting system handles 2.625.000 · 2 cycles		
Expected results: It fails to survive the fatigue test		
Possible errors: The thread cutting system is designed too fragile		

T-21.A.43-EM THREAD CUTTER LIFETIME		
Traceability test report:	**By:** Andreas Stustad	**Date:** 05.01.2012
Traceability requirement: R-21.A.22-EM	**Test type:** Module/prototype	
Requirement description: The thread cutting system should have a lifetime of 2.625.000 cycles		
TEST		
Test description: Make sure that the thread cutting system can handle the variable loads and stresses that occur in operation.		
Test execution: Test the cutting system for at least 2.625.000 cycles in operation		
Test equipment: mock-up module, TC2		
Approval criteria: The thread cutting system handles 2.625.000		
Expected results: It fails to survive the module test		
Possible errors: The thread cutting system is designed too fragile		

T-21.A.44-EM THREAD CUTTER LIFETIME SHARPNESS		
Traceability test report:	**By:** Andreas Stustad	**Date:** 05.01.2012
Traceability requirement:R-21.A.22-EM	**Test type:** Module/prototype	
Requirement description: The thread cutting system should have a lifetime of 2.625.000 cycles		
TEST		
Test description: Make sure that the thread cutter remains sharp within its lifetime		
Test execution: Test the cutting system for at least 2.625.000 cycles with threads to investigate if the cutter remains sharp		
Test equipment: mock-up module, TC2, threads		
Approval criteria: The thread cutting system remains sharp enough to easily cut thread after 2.625.000 · 2 cycles		
Expected results: It remains sharp		
Possible errors: The thread cutter knife edge is designed too small. The threads are wearing the cutter		

T-21.A.45-EM THREAD CUTTER SAFETY		
Traceability test report:	**By:** Andreas Stustad	**Date:** 05.01.2012
Traceability requirement:R-21.A.23-EM	**Test type:** physical measure	
Requirement description: It shall not be possible to insert anything bigger then objects with a diameter of 0.5cm		
TEST		
Test description: Make sure that nothing larger than Ø 5mm can be inserted into the thread cutter		
Test execution: Physically try to insert objects into the thread cutter		
Test equipment: mock-up module, TC2		
Approval criteria: No objects over Ø 5mm can be inserted into the thread cutter		
Expected results: It fails, because bigger objects can be inserted		
Possible errors: The weavers fingers or similar can be cut off during operation		

T-21.A.76-M THREAD CUTTER ACCURACY		
Traceability test report:	**By:** Andreas V	**Date:** 10.02.2012
Traceability requirement: R-21.A.66-M	**Test type:**	
Requirement description: The thread cutting system should not have a greater error then 1 of 1000 cycles		
TEST		
Test description: Make sure that the thread cutting system is able to cut the thread, with a small error margin		
Test execution: Use the module and different threads to check the effectiveness of the cutter		
Test equipment: Module, threads		
Approval criteria: The cutter fails less than once per 1000 time		
Expected results: The cutting error might be bigger		
Possible errors: The thread cutting system has a faulty design		

THREAD FEEDING SYSTEM

T-22.A.46-EM THREAD FEEDING LIFETIME		
Traceability test report:	**By:** Andreas Stustad	**Date:** 05.01.2012
Traceability requirement: R-22.A.25-M	**Test type:** Module/prototype	
Requirement description: The thread feeding system should have a lifetime of at least 5 years or 8750 working hours.		
TEST		
Test description: Make sure that the thread feeding system handles 8750 hours of operation		
Test execution: Test the thread feeding system with threads under operation		
Test equipment: mock-up module, TC2		
Approval criteria: The thread feeding system handles 8750 hours of operation		
Expected results: It passes. There is not much stresses in the system		
Possible errors: If the system fails, it is possible that threads and mechanisms stops		

T-22.A.47-EM THREAD FEEDING SUCCESS		
Traceability test report:	**By:** Andreas Stustad	**Date:** 05.01.2012
Traceability requirement:R-22.A.36-M	**Test type:** Module/prototype	
Requirement description: Threads shall never fail to be delivered or snap more than 1 out of 1000 cycles, i.e. 1‰.		
TEST		
Test description: Make sure that the threads are being delivered from the thread holding system to the thread selection system without snapping or failing in more than 1 out of 1000 cycles		
Test execution: Test the thread feeding system with threads under operation of 1000 cycles		
Test equipment: mock-up module, TC2		
Approval criteria: The thread feeding system handles 1000 cycles without the threads failing or snapping		
Expected results: It fails because of the threads jumps off		
Possible errors: The path from the thread holding system to the selection system has incomplete design, and therefore fails to deliver the threads correct. The threads can also snap because of too much tension in the system		

T-22.A.48-E THREAD FEEDING NOTIFY		
Traceability test report:	**By:** Andreas Stustad	**Date:** 05.01.2012
Traceability requirement: R-22.A.87-E	**Test type:** Module/prototype	
Requirement description: The gripper shall reduce its speed if a thread are failed to be delivered or snapped, and keep this reduced speed until it reaches its initial position.		
TEST		
Test description: Make sure that the gripper reduces its speed when the gripper does not grab the thread.		
Test execution: Test the thread feeding system with threads under operation, and cut one thread.		
Test equipment: Mock-up module.		
Approval criteria: The thread feeding system reduces its speed when a thread is cut, and returns back to its initial position.		
Expected results: The gripper does not reduce the speed because the system does not detect a snapped thread.		
Possible errors: If the system does not detect a snapped thread, the whole process will go on without a thread, resulting in incomplete fabric.		

T-22.A.70-M THREAD FEEDING BUFFER		
Traceability test report:	**By:** Andreas Stustad	**Date:** 06.02.2012
Traceability requirement: R-22.A.60-M	**Test type:** Module test	
Requirement description: The thread feeding path shall be longer than the pick itself.		
TEST		
Test description: Make sure that the thread feeding system path is longer than the pick.		
Test execution: Measure the path length between the holding system and the selection system.		
Test equipment: Measuring tape		
Approval criteria: The path is longer than the pick. On the smallest TC2, this length is 1m		
Expected results: It is longer than the pick		
Possible errors: The system cannot finish the pick if the spool becomes empty.		

T-22.A.94-E HALT ON MULTIPLE THREADS		
Traceability test report:	**By:** AS, EN	**Date:** 22.05.2012
Traceability requirement: R-22.A.86-E	**Test type:** Integration test	
Requirement description: The gripper shall halt within 10cm if multiple threads are pulled. The user will then have to press SW0-button to get the gripper back to its initial position.		
TEST		
Test description: Make sure that the gripper halts when it accidently pulls multiple threads.		
Test execution: We will trigger the possibility that two threads get pulled by the gripper, and find out if the gripper halts within 10cm.		
Test equipment: The prototype, except thread selection.		
Approval criteria: The gripper halts within 10cm when it pulls two threads.		
Expected results: The gripper halts in a distance shorter than 10cm.		
Possible errors: The system will not stop because the sensor does not register both threads at once, or we have a software bug.		

T-23.A.50-M LIFETIME		
Traceability test report:	**By:** Andreas Vander	**Date:** 06.01.2012
Traceability requirement: R-23.A.30-M	**Test type:** Module test	
Requirement description: The thread holding system should have a lifetime of 5 years.		
TEST		
Test description: Test the system if it can handle 8750 working hours.		
Test execution: Use module to test lifetime		
Test equipment: Prototype module		
Approval criteria: The system handles 8750 working hours.		
Expected results: The system handles 8750 working hours.		
Possible errors: System fails to handle 8750 working hours		

T-23.A.51-M SPOOL VARIATION		
Traceability test report:	**By:** Andreas Vander	**Date:** 06.01.2012
Traceability requirement: R-23.A.31-M	**Test type:** Module/prototype testing	
Requirement description: The holding system shall be able to hold conical spools.		
TEST		
Test description: Test the system with different adapters for spools.		
Test execution: Test all adapters for all the different spools.		
Test equipment: Module		
Approval criteria: All different types of conical spools fit.		
Expected results: Almost all types fit.		
Possible errors: Some spools do not fit.		

T-23.A.52-M CAPACITY		
Traceability test report:	**By:** Andreas Vander	**Date:** 04.01.2012
Traceability requirement: R-23.A.26-M	**Test type:** Module testing	
Requirement description: The thread holding system must be able to hold 8 spools**.**		
TEST		
Test description: Test if all 8 spools fit in the holding system.		
Test execution: Test if all 8 spools fit in the thread holding system.		
Test equipment: Module		
Approval criteria: All spools fit		
Expected results: All spools fit		
Possible errors: One or more spools do not fit.		

T-23.A.53-E NOTIFY		
Traceability test report:	**By:** Andreas Vander	**Date:** 06.01.2012
Traceability requirement: R-23.A.28-E	**Test type:** Module/prototype testing	
Requirement description: Thread holding system notify user when spools are becoming empty.		
TEST		
Test description: Test if system notify user when empty		
Test execution: Test with whole system.		
Test equipment: Prototype/module		
Approval criteria: System notify user		
Expected results: System notify user		
Possible errors: System does not notify the user.		

T-23.A.68-M THREAD RESISTANCE - STRAIGHT OFF CONICAL SPOOL		
Traceability test report:	**By:** EN, AS	**Date:** 06.02.2012
Traceability requirement: R-23.A.59-M	**Test type:** Test of concept	
Requirement description: The threads must be easily pulled off the spools. The spools are vertical and not rotating.		
TEST		
Test description: The resistance is visually tested.		
Test execution: Group members visually judge the resistance in the thread while it's pulled straight upwards, with a center hole a few centimeters above the conical spool.		
Test equipment: Lego prototype module with center hole, two different conical spools.		
Approval criteria: There can't be much tension in the thread while it's pulled off the spool.		
Expected results: The thread on conical spools will easily be pulled off.		
Possible errors: It needs too much force to pull of the thread.		

T-23.A.99-M THREAD RESISTANCE - STRAIGHT OFF CYLINDRICAL SPOOL		
Traceability test report:	**By:** EN, AS	**Date:** 06.02.2012
Traceability requirement: R-23.A.59-M	**Test type:** Test of concept	
Requirement description: The threads must be easily pulled of the spools. The spools are vertical and not rotating.		
TEST		
Test description: The resistance is visually tested.		
Test execution: Group members visually judge the resistance in the thread while it's pulled straight upwards, with a center hole a few centimeters above the cylindrical spool.		
Test equipment: Lego prototype module with center hole, two different cylindrical spools.		
Approval criteria: There can't be much tension in the thread while it's pulled off the spool.		
Expected results: The thread on cylindrical spools will be a bit tricky to pull off because the angle from the outer circumference of the spool, and up to the center hole, is negative. This will create a lot of friction on the loose thread on its way to the center hole.		
Possible errors: It needs too much force to pull of the thread.		

T-23.A.100-M THREAD RESISTANCE - CYLINDRICAL SPOOL WITH ARM		
Traceability test report:	**By:** EN, AS	**Date:** 06.02.2012
Traceability requirement: R-23.A.59-M	**Test type:** Test of concept	
Requirement description: The threads must be easily pulled off the spools. The spools are vertical and not rotating.		
TEST		
Test description: The resistance is visually tested.		
Test execution: Group members visually judge the resistance in the thread. In this test we have added a rotating arm at the top of the spool, and threaded the thread through a hole in this arm. Figure 5 illustrates how this will be done.  Figure 5: Spool with arm		
Test equipment: Lego prototype module with rotating arm, one cylindrical spool.		
Approval criteria: There can't be much tension in the thread while it's pulled off the spool.		
Expected results: With this rotating arm, we will get a positive angle of the thread off the spool. This will cause the thread to go easier off the spool.		
Possible errors: The arm gets stuck while it's spinning because of the upward going force from the thread. Another possibility is that the arm will not be able to stop when it is supposed to, because of its moment of inertia.		

T-23.A.101-M THREAD RESISTANCE - WITH BIG DISC

Traceability test report:	**By:** EN, AS	**Date:** 13.02.2012
Traceability requirement: R-23.A.59-M	**Test type:** Test of concept	

Requirement description: The threads must be easily pulled off the spools. The spools are vertical and not rotating.

TEST

Test description: The resistance is visually tested.

Test execution: Group members visually judge the resistance in the thread. In this test we have mounted a disc that is considerably wider than the spool. The thread is then threaded through a center hole, as illustrated in Figure 6.

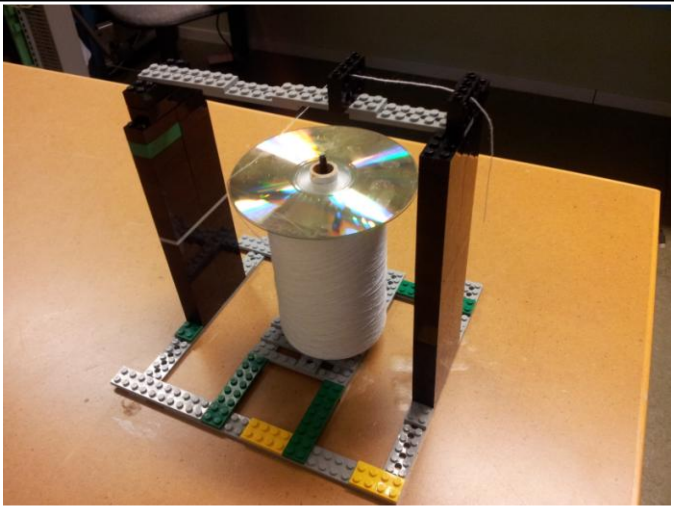

Figure 6: Spool with big disc

Test equipment: Lego prototype module with a big disc, and one cylindrical spool.

Approval criteria: There can't be much tension in the thread while it's pulled off the spool.

Expected results: It will now be easier to pull out the thread on the cylindrical spool, and we have no moving part which will result in self-spinning.

Possible errors: Friction on the disc itself might occur.

T-23.A.102-M THREAD RESISTANCE - WITH SMALLER DISC

Traceability test report:	**By:** EN, AS	**Date:** 13.02.2012
Traceability requirement: R-23.A.59-M	**Test type:** Test of concept	

Requirement description: The threads must be easily pulled off the spools. The spools are vertical and not rotating.

TEST

Test description: The resistance is visually tested.

Test execution: Group members visually judge the resistance in the thread. In this test we have mounted a smaller disc than the disc in test T-23.A.101-M. The thread is then threaded through a center hole, as illustrated in Figure 7, Figure 8 and Figure 9.

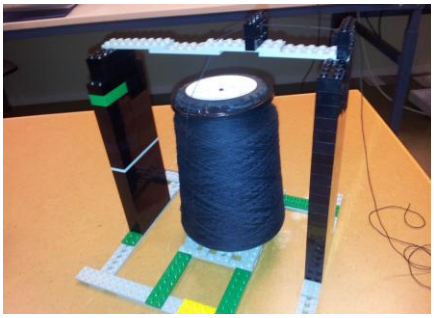

Figure 8: Small disc with conical spool

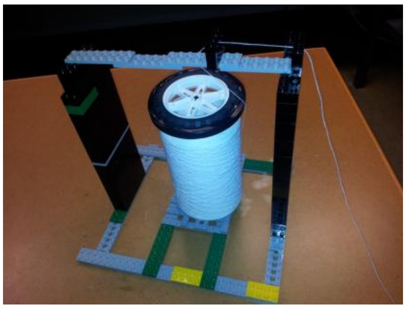

Figure 7: Small disc with big cylindrical spool

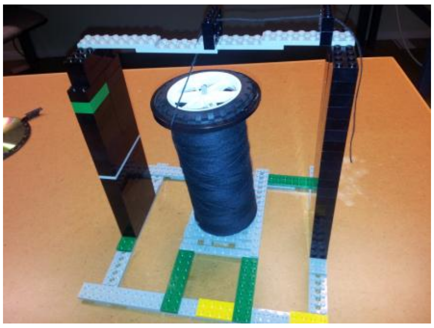

Figure 9: Small disc with small cylindrical spool

Test equipment: Lego prototype module with a small disc, and three different spools, conical and cylindrical.

Approval criteria: There can't be much tension in the thread while it's pulled off the spool.

Expected results: It will now be easier to pull out the thread on the cylindrical spool because we get more out of the upward force.

Possible errors: Friction on the disc itself might occur.

T-23.A.103-M THREAD RESISTANCE - WITH BUFFER		
Traceability test report:	**By:** EN, AS	**Date:** 16.02.2012
Traceability requirement: R-23.A.59-M	**Test type:** Test of concept	
Requirement description: The threads must be easily pulled off the spools. The spools are vertical and not rotating.		
TEST		
Test description: The resistance is visually tested.		
Test execution: We will use a Lego-built room with two pulley wheels on one of the sides of the room and a hole at the bottom of the opposite side of the room. The two pulley wheels will push thread into the room. Later, the thread will be pulled out of the hole at the bottom.		
Test equipment: Lego prototype module for buffer circuit, Lego-motor and a spool.		
Approval criteria: There can't be much tension in the thread while it's pulled off the spool.		
Expected results: We might have problems with stuck yarn, but beside that the thread will move much more smoothly.		
Possible errors: The room will be filled up with thread, which may lead to knots on the thread.		

T-23.A.78-EM ARM BRAKE

Traceability test report:	**By:** EN,	**Date:** 23.02.2012
Traceability requirement: R-23.A.68-EM	**Test type:** Prototype test	

Requirement description: The rotating arm shall not rotate more than 45 degrees after the thread is no longer moving.

TEST

Test description: We will find out whether the arm is stopping before 45 degrees after the thread is no more moving. The result will be given with a high speed camera.

Test execution: The thread must be pulled out with a speed and acceleration equal to the gripper. The brake module will be activated by the yarn sensor.

Test equipment: High speed camera, yarn sensor, brake module, spool, center-axle for the spool.

Approval criteria: The thread arm must stop within 45 degrees.

Expected results: It will be problematic to have this fast reaction of this fast-spinning arm. It will most likely stop after a while, but the requirement of 45 degrees might be too heavy.

Possible errors: The braking mechanism will stop too early or too late. If it stops too early, it might destroy some of our components. If it stops too late, the thread will spin around itself, and get stuck for the next pick.

T-30.A.54-E OPERATIONAL VOLTAGE		
Traceability test report: Test report (D-03.A.20-A)	**By:** EN	**Date:** 06.01.2012
Traceability requirement: R-30.A.44-E	**Test type:** Voltage measurement	
Requirement description: The operational voltage of the microcontroller shall be 12 volt or less.		
TEST		
Test description: Make sure that the power voltage of the microcontroller is less than, or equal to 12V.		
Test execution: The voltage on the microcontroller's input voltage is measured.		
Test equipment: Voltmeter, Fluke, multi meter or Fluke.		
Approval criteria: The voltage is not higher than 12 volt.		
Expected results: The voltage is not higher than 12 volt.		
Possible errors: If the voltage is higher than we predicted, the components on the control unit may be damaged.		

T-30.A.57-E SENSOR INPUT SW		
Traceability test report:	**By:** Eirik Nordstrand	**Date:** 06.01.2012
Traceability requirement: R-30.A.48-E	**Test type:** Compilation readings	
Requirement description: The microcontroller shall receive sensor data from the sensors on the spools, gripper path (in parallel with the gripper arm to check for objects in the gripper's path) and gripper position.		
TEST		
Test description: Make sure that the microcontroller receives values from all the sensors in our module.		
Test execution: All the sensors will be trigged manually and individually, and we will read the values on the microcontroller's compiler.		
Test equipment: Nothing, except the equipment pre-installed on our module.		
Approval criteria: All sensors give the correct values to the microcontroller.		
Expected results: The first time we do this, we will most likely have some errors, but after some trouble shooting, we will have it correct.		
Possible errors: Programming errors, calculation errors, loose cables, wrong connected cables.		

T-30.A.58-E EMERGENCY SHUTDOWN		
Traceability test report:	**By:** Eirik Nordstrand	**Date:** 07.01.2012
Traceability requirement: R-30.A.52-E	**Test type:** Voltage measurement	
Requirement description: The microcontroller shall halt the system immediately if the user presses the emergency shutdown button.		
TEST		
Test description: Make sure that the system does not continue running right after the emergency button is pressed. The gripper is allowed to move 0.5 cm after it's pressed.		
Test execution: Ensure that the 12V voltage supply is lost, and that there's no capacitors etc. that keeps the system running.		
Test equipment: Oscilloscope		
Approval criteria: All voltage are gone immediately, and the system halts		
Expected results: The system will stop, but the gripper will probably continue more than 0.5 cm because there will be no breaks on the gripper arm without power.		
Possible errors: Spikes, too slow discharge, too slow stop on the gripper arm, delays in the microcontroller.		

T-30.A.89-E COMMUNICATION		
Traceability test report:	**By:** Inge Ytre-Eide	**Date:** 30.04.2012
Traceability requirement: R-30.A.85-E	**Test type:** Operation test	
Requirement description: The microcontroller shall communicate with the Faulhaber MCBL 2805 by serial on a 9600 baud rate		
TEST		
Test description: Test the designed program for Atmega128 to check for compability with the Faulhaber MCBL 2805 controller		
Test execution: Send primitive commands over the serial.		
Test equipment: ATmega128RFA1, Faulhaber MCBL 2805, Oscilloscope		
Approval criteria: The Faulhaber receives the commands and does as intended by the commands		
Expected results: The Faulhaber and Atmega will behave as expected.		
Possible errors: Registers may not be set properly, problems with calibrating the serial (i.e. baud rate)		

T-30.A.95-E ANALOG COMPARATOR INPUT VOLTAGES		
Traceability test report:	**By:** Eirik Nordstrand	**Date:** 21.05.2012
Traceability requirement: R-30.A.88-E	**Test type:** Voltage measurements	
Requirement description: The analog comparator output (ACO) shall be low when the voltage from the weft sensor is lower than the reference voltages (0.5V and 1.3V), and vice versa.		
TEST		
Test description: Make sure that the input pins on the analog comparator on the STK600 have the correct voltages.		
Test execution: Do voltage measurements on PE2, PE3 and PF0 to ensure that all the pins have the correct voltages.		
Test equipment: ATmega128RFA1, G3W weft sensor, multi meter		
Approval criteria: The voltage on the pins on the STK600 must be almost the same as the outputs from the sensor and the voltage reference sources.		
Expected results: We will measure the same voltage on the pins when the sensor and voltage references are connected, as we did while these are not connected to the pin.		
Possible errors: Something is wrong with the card.		

SENSORS

T-31.A.62-E SPOOL SIZE

Traceability test report:	**By:** Eirik Nordstrand	**Date:** 07.01.2012
Traceability requirement: R-31.A.51-E	**Test type:** Voltage measurement	
Requirement description: There shall be sensors on each spool to warn the system when it is, or soon is, no more thread on the spool.		
TEST		
Test description: Make sure that the sensors warn when there's a little thread left.		
Test execution: Ensure that the sensors are trigging when there's soon no more thread left on the spool. This can be tested by pulling thread from an almost empty spool, and find out if the sensors are trigging.		
Test equipment: Multi meter or scope.		
Approval criteria: All the sensors are mounted correctly, and the sensors are trigging, but some calibration will be likely.		
Expected results: All the sensors are mounted correctly, and the sensors are trigging, but some calibration will be likely.		
Possible errors: Sensors not fastened well enough or in wrong direction, sensors connected wrong.		

T-31.A.63-E DOOR SAFETY

Traceability test report:	**By:** Eirik Nordstrand	**Date:** 07.01.2012
Traceability requirement: R-31.A.56-E	**Test type:** Voltage measurement	
Requirement description: The system shall halt when the maintenance doors for the spools are open.		
TEST		
Test description: Make sure that the sensors give the microcontroller a signal that will halt the system.		
Test execution: Ensure that the sensors are trigging when doors are opening.		
Test equipment: Multi meter or scope.		
Approval criteria: All the sensors are mounted correctly, and the sensors are trigging.		
Expected results: All the sensors are mounted correctly, and the sensors are trigging.		
Possible errors: Sensors not fastened well enough or in wrong direction, sensors connected wrong.		

T-31.A.66-E YARN SENSOR - INPUT VOLTAGE

Traceability test report:	**By:** Eirik Nordstrand	**Date:** 02.02.2012
Traceability requirement: R-31.A.57-E	**Test type:** Visual test	
Requirement description: The sensor shall be turned on when 24 volt is connected.		
TEST		
Test description: Make sure that the sensor is functioning and turns on when the it's powered with 24 volt.		
Test execution: Ensure that LED's are indicating that the sensor is up and running.		
Test equipment: Human eye.		
Approval criteria: The sensor is working, and the LEDs are blinking or constantly lighting.		
Expected results: The sensor is working, and the LEDs are blinking or constantly lighting.		
Possible errors: The sensor may be DOA, or the LEDs are not supposed to emit light when it's powered.		

T-31.A.67-E YARN SENSOR - OUTPUT VOLTAGE		
Traceability test report:	**By:** Eirik Nordstrand	**Date:** 02.02.2012
Traceability requirement: R-31.A.58-E	**Test type:** Voltage measurement	
Requirement description: The sensor shall give a constant output while the thread is moving, and give another voltage when the thread is not moving. It should also give an individual voltage if too many threads are moving.		
TEST		
Test description: Make sure that the sensor gives an output when the yarn is moving.		
Test execution: Use a motor to spin, and then not spin, thread from the spool, through the sensor. Control that the measurement instrument indicates a change of voltage.		
Test equipment: Multi meter or scope, and a motor.		
Approval criteria: The sensor gives an output when the yarn is moving.		
Expected results: Some problems will occur, but we will get it to work in the end.		
Possible errors: Too high voltage or too much current load can damage the sensor.		

CASING

T-40.A.20-M DESIGN		
Traceability test report:	**By:** VK	**Date:** 05.01.2012
Traceability requirement:R-40.A.32-M	**Test type:** Visual test	
Requirement description: The casing should match existing design of the TC2, within the limitations set by Tronrud Engineering.		
TEST		
Test description: Get feedback from Tronrud engineering about our CAD design.		
Test execution: Contact Tronrud engineering with our CAD design for casing		
Test equipment: Computer, Mail.		
Approval criteria: Design is approved.		
Expected results: Design is approved.		
Possible errors: Missing feedback.		

T-40.A.21-M MAINTENANCE		
Traceability test report:	**By:** VK	**Date:** 05.01.2012
Traceability requirement:R-40.A.33-M	**Test type:** Visually test	
Requirement description: The casing shall be equipped with doors so that accessing the spools and threads are easy.		
TEST		
Test description: The group will visually decide if casing door and accessing to the spools is approval.		
Test execution: The group sees the design and decides if it is good enough.		
Test equipment: Computer.		
Approval criteria: Design is approved.		
Expected results: Design is approved.		
Possible errors: The group can't reach agreement.		

T-40.A.22-M DURABILITY		
Traceability test report:	**By:** VK	**Date:** 05.01.2012
Traceability requirement:R-40.A.34-M	**Test type:** FEM analysis	
Requirement description: The attachments of the casing should be robust enough to carry the modules weight and vibrations in operation.		
TEST		
Test description: Make a stress analysis by using Solidworks.		
Test execution: Make a stress analysis by using Solidworks.		
Test equipment: Solidworks CAD software, Solidworks simulation software, Computer, CAD files of ASCS-module.		
Approval criteria: Casing is robust enough to carry the modules weight and vibrations in operation.		
Expected results: Casing is robust enough to carry the modules weight and vibrations in operation.		
Possible errors: Computer crash, power loss.		

T-40.A.23-M FIXING POINTS		
Traceability test report:	**By:** VK	**Date:** 05.01.2012
Traceability requirement: R-40.A.37-M	**Test type:** Measuring test	
Requirement description: The fixing points for the casing and the module shall use the four 6mm existing bolt holes for the front plate of the TC2.		
TEST		
Test description: Measure fixing points for the casing and the module by using Solidworks.		
Test execution: Measure fixing points for the casing and the module by using Solidworks.		
Test equipment: Solidworks CAD software, Solidworks simulation software, Computer, CAD files of ASCS-module.		
Approval criteria: The fixing points for the casing and the module are using the four 6mm existing bolt holes.		
Expected results: The fixing points for the casing and the module are using four 6mm existing bolt holes for the front plate of the TC2.		
Possible errors: Computer crash, power loss.		

T-40.A.71-M CASING THICKNESS		
Traceability test report:	**By:** Andreas Stustad	**Date:** 06.02.2012
Traceability requirement: R-40.A.61-M	**Test type:** prototype test	
Requirement description: The casing shall be minimum 1 mm thick		
TEST		
Test description: Measure the thickness of the metal plates		
Test execution: Measure the thickness with measuring tool		
Test equipment: measuring tool (slide gauge)		
Approval criteria: The panels are 1 mm +/- 0.2 mm included paint		
Expected results: The panels holds the correct thickness		
Possible errors: The panels are produced wrong or has too much paint		

T-40.A.72-M CHASSIS THICKNESS		
Traceability test report:	**By:** Andreas Stustad	**Date:** 06.02.2012
Traceability requirement: R-40.A.62-M	**Test type:** prototype test	
Requirement description: The chassis for the module shall be minimum 2.5 mm thick		
TEST		
Test description: Measure the thickness of the metal plate		
Test execution: Measure the thickness with measuring tool		
Test equipment: Slide gauge		
Approval criteria: The panels are 2.5 mm +/- 0.3 mm included paint		
Expected results: The panels holds the correct thickness		
Possible errors: The panels are produced wrong or has too much paint		

T-40.A.73-M SYSTEM MOUNTING		
Traceability test report:	**By:** Andreas Stustad	**Date:** 06.02.2012
Traceability requirement:R-40.A.63-M	**Test type:** prototype test	
Requirement description: The system shall be mounted to the chassis plate		
TEST		
Test description: Mount the modules to the chassis plate to see if the they fit		
Test execution: Mount every module to the chassis and make sure that the do not interrupt each other or crash		
Test equipment: mockup TC2, mockup modules		
Approval criteria: The modules can be mounted and are working without crashing with each other		
Expected results: The modules fits without interacting with each other		
Possible errors: We must redesign some of the modules or the space		

THE SYSTEM

T-00.B.30-EM REPLACING SPOOL		
Traceability test report:	**By:** VK	**Date:** 06.01.2012
Traceability requirement: R-00.B.38-EM	**Test type:** Prototype test	
Requirement description: The whole sequence of changing a spool and laying the thread through the thread feeding system shall take no more than 5 minutes.		
TEST		
Test description: One or several members of the group will try to change a spool and lay a thread.		
Test execution: The time is taken while the sequence is performed.		
Test equipment: Prototype of ASCS-module, stopwatch		
Approval criteria: The sequence takes less than 5 minutes.		
Expected results: The sequence takes less than 5 minutes.		
Possible errors: Unable to finish the prototype module.		

T-00.B.31-E SYSTEM RESET

Traceability test report:	**By:** VK	**Date:** 06.01.2012
Traceability requirement: R-00.B.24-E	**Test type:** Prototype test	
Requirement description: When the emergency button is pushed, the system shall reset.		
TEST		
Test description: One or several group members perform the test.		
Test execution: First of all the system is started, then the emergency button is pushed.		
Test equipment: Prototype of ASCS-module.		
Approval criteria: The system resets.		
Expected results: The system resets.		
Possible errors: Unable to finish the prototype module.		

GRIPPER

T-10.B.27-M	REPLACE TIME	
Traceability test report:	**By:** VK	**Date:** 06.01.2012
Traceability requirement:R-10.B.03-M	**Test type:** Prototype test	
Requirement description: Replacing the gripper shouldn't take more than 20 minutes.		
TEST		
Test description: One or several members of the group will try to replace the gripper.		
Test execution: The time is taken while the gripper is being replaced with the same gripper.		
Test equipment: Prototype of ASCS-module, stopwatch.		
Approval criteria: Replacing the gripper will not take more than 20 minutes.		
Expected results: Replacing the gripper will not take more than 20 minutes.		
Possible errors: Unable to finish the prototype module.		

T-10.B.28-EM	REPLACE SKILLS	
Traceability test report:	**By:** VK	**Date:** 06.01.2012
Traceability requirement:R-10.B.04-EM	**Test type:** Prototype test	
Requirement description: Replacing the gripper shouldn't require any technical education/knowledge.		
TEST		
Test description: Persons outside the group will perform the test.		
Test execution: The user will get an introduction to how the system works. The user will try to change the gripper.		
Test equipment: Prototype of ASCS-module		
Approval criteria: Replacing the gripper does not require any technical education/knowledge.		
Expected results: Replacing the gripper does not require any technical education/knowledge.		
Possible errors: Unable to finish the prototype module.		

T-23.B.88-EM SPOOL VARIATION		
Traceability test report:	**By:** AS	**Date:** 08.03.2012
Traceability requirement: R-23.A.77-EM	**Test type:** Prototype test	
Requirement description: The system shall be able to hold cylindrical spools		
TEST		
Test description: Test the module to see if cylindrical spools fit and can be used.		
Test execution: Mount cylindrical spools to the module.		
Test equipment: Prototype, spools		
Approval criteria: The spools can be mounted and are fully functional		
Expected results: The spools fits		
Possible errors: If the cylindrical spools does not fit or cannot be used, the system needs to be redesigned.		

TEST REPORT FOR THE "AUTOMATIC SHUTTLE CONTROL SYSTEM"

D-03.A.20-A

Release 2.0

TRONRUD ENGINEERING AS

RELEASE NOTES

Date	Version	Description	Author
06.02.2012	0.1	- First draft	Eirik Nordstrand
10.02.2012	0.2	- Fixed the incorrect version number - Fixed front page - Added test report for spool holding system. -Updated "About this document"	Eirik Nordstrand
13.02.2012	0.2.1	-Added tests for spool holding	Eirik Nordstrand
16.02.2012	0.2.2	- Added tests for spool holding	Eirik Nordstrand
24.02.2012	0.2.3	- Added tests for yarn break sensor input- and output voltage	Eirik Nordstrand
14.03.2012	1.0	- Finalized document	Eirik Nordstrand
04.05.2012	1.1	Added tests for module 23/22	Eirik Nordstrand
08.05.2012	1.2	- Added tests completed for module 14 and 00	Mats Strand Sætervik
09.05.2012	1.3	- Added test report for thread sensor and Atmel	Eirik Nordstrand
10.05.2012	1.3.1	- Added test T-40.A.22-M	Andreas Stustad
11.05.2012	1.3.2	- Added new test for module 14	Mats Strand Sætervik
15.05.2012	1.4	- Added tests: T-40.A.20-M, T-40.A.21-M T-40.A.23-M, T-40.A.71-M T-40.A.72-M	Andreas Stustad
19.05.2012	1.4.1	- Added tests to module 12 and 14	Mats Strand Sætervik
21.05.2012	1.5	- Added tests T-23.A.51-M, T-23.A.52-M, T-43.B.88-EM - Grammar and spelling	Andreas Stustad
21.05.2012	1.5.1	Added tests: T-10.A.13-M, T-12.A.16-EM	Vazgen Karlsen
22.05.2012	1.5.2	Added tests: T-23.A.52-M	Andreas Vander
22.05.2012	1.5.3	Updated T-22.A.48-E, T-22.A.70-M, T-22.A.94-E, T-23.A.53-E,	Eirik Nordstrand
23.05.2012	1.5.4	Added T-30.A.95-E	Eirik Nordstrand
24.05.2012	1.5.5	Edited tests for module 14	Mats Strand Sætervik
25.05.2012	1.5.6	Added T-40.A.73-M	Andreas Stustad
26.05.2012	1.5.7	Added tests: T-10.A.12-EM Added document number on all tests	Mats Strand Sætervik

26.05.2012	1.6	Moved tests for module 23 from test report to test spec	Eirik Nordstrand
28.05.2012	1.6.1	Added several test reports for module 10,11 and 12	Vazgen Karlsen
29.05.2012	1.6.2	Added table of figures	Mats Strand Sætervik
29.05.2012	1.6.3	Completed information for test reports of module 10, 11 and 12.	Vazgen Karlsen
29.05.2012	2.0	Finalized document	Eirik Nordstrand

ABOUT THIS DOCUMENT

This document is a report of the different tests we have done. The tests specification for each of the tests is described in Testspec_D-03.A.08-A, and the plan for the tests is described in Tests plan_ D-03.A.30-A.

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INTRODUCTION

This document contains most of our tests. All of these tests and how they are going to be conducted is explained in Test specification (D-03.A.08). Some tests have their own test report, due to large amount of information the Test specification refers to these.

Every module is listed in the document "Project Plan" (D-00.A.00-A). The tests are in addition, divided into A, B or C priorities, which describe the tests importance in the project. Each test has a table, and each box in the test table has different information. The explanation for the code system is also given in the document "Project Plan" (D-00.A.00-A).

Each test report contains the following information:

- **Title:**
  The title of each test contains three things. The test number, test spec name and a short description of what was tested. This could be a specific component name, or a how many cycles where planned.
- **Traceability requirement:**
  This refers which requirement the test is related to. One requirement may have several tests, so one approved doesn't necessary means that the requirement is approved.
- **Document number:**
  If a extra document is used to describe the test results, the document number is written here. This could for example be the result of a FEM analysis.
- **Responsible:**
  The name of the persons who perform the test and has written the report
- **Execution date:**
  When the test was executed
- **Test type:**
  Describes what kind of test was done. This could for example be physical measurement of voltages, currents, size measurements or software test.
- **Test number:**
  If improvements are needed and test specification still is correct, several test with improvements can be done.
- **Expected results:**

Is the expected result, the result should reflect measuring type and match the requirement if the test is believed to fulfill the requirement.

- **Actual results:**

  What is being observed when the test is being performed

- **Error description:**

  If any errors have occurred, the most likely cause of these errors has be described here.

- **Improvement:**

  If any errors have occurred, improvements to remove these errors can be suggested here. Another test is needed to test these improvements.

- **Approved:**

  A test can be not approved or not approved.

A-TESTS

MODULE 00: THE ENTIRE SYSTEM

T-00.A.25-E EMERGENCY BUTTON – SOFTWARE STOP

Traceability requirement: R-00.A.13-E	**Responsible:** MSS	**Execution date:** 01.05.2012
Document number:	**Test type:** Physical measurement	**Test number:** 1

Requirement description: When the emergency button is pushed, the system shall halt at once.

TEST

Expected results: When the emergency button is pushed, the system stops at once.

Actual results:

When SW2 (switch 2) is pressed the system enables the brake for the feeding mechanism and the motor for the feeding mechanism stops. The system waits for SW0 (switch 0) is pressed.

When switch 0 is pressed the gripper arm returns to the start position.

INFORMATION

Number of errors: 1

Error description:

No emergency button has been mounted.

Even though the system stops there isn't a physical connection that stops the motor.

Improvements:

In order to exclude software errors, the emergency switch has to physically disable/brake the motor for the feeding mechanism.

Approved: Not approved

MODULE 10: THE GRIPPER

T-10.A.12-EM SUCCESS RATE

Traceability requirement:R-10.A.00-EM	**Responsible:** VK, EN, MSS, AV	**Execution date:** 25.05.2012
Document number:	**Test type:**Full system test	**Test number:**1

Requirement description: The gripper shall never fail to grab thread more than 1 out of 1000 cycles, i.e. 1‰

TEST

Expected results: The gripper fails less than 10 out of 10 000 cycles.

Actual results:

The thread snapped after 80 cycles, 2 of the cycles were unsuccessful, but the system managed to grab a new thread by itself.

10 out of the 100 cycles are filmed. In can be found under attachments -> Full system test.

INFORMATION

Number of errors: 4

Error description:

- The holder/cutter didn't catch the thread on 2 of the 80 cycles.
- The cut thread length varied with about 2 cm.
- The thread end sometimes returns into the warp when cut.
- The weft sensor was disabled, because of ongoing error repair. The weft sensor also requires that the

Improvements:

- Do the test again with the weft sensor active
- In this test the timing of the holder release is done by the feeding motor output pulses, this can be changed so it's timed by the Faulhaber moving the thread arm. This motor has a much higher resolution. It is also possible to improve the timing with the feeding motor by tuning the software.
- Changing the gripper form and change the cutter timing may improve the laying of the thread
- Moving the position may result in less weir on the thread.

Approved: Not approved

T-10.A.13-M GRIPPER LIFE TIME FEM

Traceability requirement: R-10.A.01-M	**Responsible:** VK	**Execution date:** 25.03.2012
Document number: D-03.A.31-M	**Test type:** FEM analysis	**Test number:** 1

Requirement description: The gripper should have a lifetime of at least 1 year or 1875 working hours.

Calculation of cycles per year:
25 cycles/min ·60min = 1500 cycles/hour.
1875 working hours ·1500 cycles/hour = 2 812 500 cycles.

TEST

Expected results: One or multiple parts fail**.**

Actual results:

Results from stress and fatigue analyses shows that the gripper has a lifetime of at least 1 year. These results are only an approximately picture of its real life, but are good enough to conclude that the gripper will withstand the stresses that occur.

INFORMATION

Number of errors: 0

Error description:
No errors occurred

Improvements:
More accurate S-N curve could be used to improve lifetime distribution.

Approved: Approved

T-10.A.32-EM GRIPPER HEIGHT SW		
Traceability requirement:R-10.A.54-EM	**Responsible:** VK	**Execution date:** 25.03.2012
Document number:	**Test type:** SW measurement	**Test number:**1
Requirement description: The height of the gripper shall be less than 19,2mm		
TEST		
Expected results: The height of the gripper is measured with SolidWorks measurement tool to be less than 19,2mm.		
Actual results: By using SolidWorks measurement tool the gripper is measured to be 19mm.		
INFORMATION		
Number of errors: 0		
Error description: No errors occurred		
Improvements: No improvements		
Approved: Yes		

T-10.A.33-EM GRIPPER HEIGHT

Traceability requirement: R-10.A.54-EM	**Responsible:** VK	**Execution date:** 24.05.2012
Document number:	**Test type:** Physical measurement	**Test number:** 1

Requirement description:

The height of the gripper shall be less than 19,2mm

TEST

Expected results: The height of the gripper is measured by caliper to be less than 19,2mm

Actual results:

By using caliper height of the gripper is measured to be 18.4mm.

INFORMATION

Number of errors: 0

Error description:

No errors occurred

Improvements:

- The hook can be directly attached to the gripper arm that would reduce height to around 12 mm.
- The angle of the hook can be reduced, that will also reduce gripper height.

Approved: Yes

Traceability requirement:R-10.A.55-EM	**Responsible:** VK	**Execution date:** 25.03.2012
Document number:	**Test type:** SW measurement	**Test number:**1

Requirement description:

The width of the gripper shall be far less than 157,3mm / 2 = 78,5mm

This is half of the shed width.

TEST

Expected results The width of the gripper is measured by SolidWorks measurement tool to be less than 78,5mm.

Actual results:

Width of the gripper is measured by SolidWorks measurement tool to be 22 mm.

INFORMATION

Number of errors: 0

Error description:

No errors occurred

Improvements:

No improvements.

Approved: Yes

T-10.A.35-EM GRIPPER WIDTH		
Traceability requirement:R-10.A.55-EM	**Responsible:** VK	**Execution date:** 24.05.2012
Document number:	**Test type:** Physical measurement	**Test number:**1
Requirement description: The width of the gripper shall be far less than 157,3mm / 2 = 78,5mm This is half of the shed width.		
TEST		
Expected results: By a caliper the width of the gripper is measured to be less than 78,5mm.		
Actual results: By caliper width of the gripper is measured to be 22.5 mm. It is a little bit bigger than it was designed, but still under 78,5 mm.		
INFORMATION		
Number of errors: 0		
Error description: No errors occurred		
Improvements: No improvements.		
Approved: Yes		

T-11.A.00-M GRIPPER WIDTH SW

Traceability requirement: R-11.A.06-M	**Responsible:** VK	**Execution date:** 25.03.2012
Document number:	**Test type:** SW measurement	**Test number:**1
Requirement description: The length of the arm shall be at least 1000mm.		
TEST		
Expected results The gripper arm is measured by SolidWorks measurement tool to be longer than 1000mm.		
Actual results: The gripper arm is measured by SolidWorks measurement tool to be longer than 1000mm.		
INFORMATION		
Number of errors: 0		
Error description: No errors occurred		
Improvements: No improvements.		
Approved: Yes		

T-11.A.01-M GRIPPER ARM LENGTH		
Traceability requirement: R-11.A.06-M	**Responsible:** VK	**Execution date:** 24.05.2012
Document number:	**Test type:** Physical measurement	**Test number:**1
Requirement description: Gripper arm length shall be at least 1000 mm.		
TEST		
Expected results: The gripper arm is measured by a caliper to be longer than 1000 mm.		
Actual results: The gripper arm is longer than 1000 mm and can also be adjusted because it is preexisting part that can be cut to desirable length.		
INFORMATION		
Number of errors: 0		
Error description: No errors occurred		
Improvements: No improvements.		
Approved: Yes		

T-11.A.02-M GRIPPER ARM WIDTH SW		
Traceability requirement: R-11.A.27-M	**Responsible:** VK	**Execution date:** 25.03.2012
Document number:	**Test type:** SW measurement	**Test number:**1
Requirement description: Gripper arm shall be far less than 125,8mm in width**.**		
TEST		
Expected results The gripper arm width is measured by SolidWorks measurement tool to be smaller than 125,8mm		
Actual results: The gripper arm width is measured by SolidWorks measurement tool to be 2,5 mm. That is far less than 125,8mm.		
INFORMATION		
Number of errors: 0		
Error description: No errors occurred		
Improvements: No improvements.		
Approved: Yes		

T-11.A.03-M GRIPPER ARM WIDTH

Traceability requirement: R-11.A.27-M	**Responsible:** VK	**Execution date:** 24.05.2012
Document number:	**Test type:** Physical measurement	**Test number:**1

Requirement description:

Gripper arm shall be far less than 125,8mm in width.

TEST

Expected results: By using a caliper the gripper arm width is measured to be smaller than 125,8mm.

Actual results:

The actual gripper arm width is measured by caliper to be 2,5 mm, far less than 128,5mm.

INFORMATION

Number of errors: 0

Error description:

No errors occurred

Improvements:

No improvements.

Approved: Yes

T-11.A.04-M GRIPPER ARM HEIGHT SW		
Traceability requirement: R-11.A.35-M	**Responsible:** VK	**Execution date:** 26.03.2012
Document number:	**Test type:** SW measurement	**Test number:**1
Requirement description: The height of the gripper arm shall be less than 19,2mm		
TEST		
Expected results The gripper arm height is measured by SolidWorks measurement tool to be less than 19,2mm.		
Actual results: The gripper arm height is measured by SolidWorks measurement tool to be 5 mm.		
INFORMATION		
Number of errors: 0		
Error description: No errors occurred		
Improvements: No improvements.		
Approved: Yes		

T-11.A.05-M GRIPPER ARM HEIGHT		
Traceability requirement: R-11.A.35-M	**Responsible:** VK	**Execution date:** 24.05.2012
Document number:	**Test type:** Physical measurement	**Test number:**1
Requirement description: The height of the gripper arm shall be less than 19,2mm		
TEST		
Expected results: By using caliper the gripper arm height is measured to be less than 19,2mm		
Actual results: The actual gripper arm height is measured by caliper to be 5 mm. Far less than 19,2mm.		
INFORMATION		
Number of errors: 0		
Error description: No errors occurred		
Improvements: No improvements.		
Approved: Yes		

T-11.A.06-M GRIPPER ARM STORAGE SPACE SW		
Traceability requirement: R-11.A.07-M	**Responsible:** VK	**Execution date:** 26.03.2012
Document number:	**Test type:** SW measurement	**Test number:**1
Requirement description: The storage space for the gripper arm is limited by the total area for the module, so it has to be stored without standing in the way for other components.		
TEST		
Expected results The gripper arm catches or stand in the way of other components.		
Actual results: By placing the gripper arm in CAD assembly of ASCS module it shows that it can be stored without standing in the way for other components.		
INFORMATION		
Number of errors: 0		
Error description: No errors occurred		
Improvements: No improvements.		
Approved: Yes		

T-11.A.07-M GRIPPER ARM STORAGE SPACE		
Traceability requirement: R-11.A.07-M	**Responsible:** VK	**Execution date:** 24.05.2012
Document number:	**Test type:** Prototype test	**Test number:**1
Requirement description: The storage space for the gripper arm is limited by the total area for the module, so it has to be stored without standing in the way for other components.		
TEST		
Expected results The gripper arm catches or stand in the way of other components.		
Actual results: The actual result of prototype shows that the gripper arm can be stored without standing in the way for other components.		
INFORMATION		
Number of errors: 0		
Error description: No errors occurred		
Improvements: No improvements.		
Approved: Yes		

T-11.A.08-M GRIPPER ARM LIFETIME SW		
Traceability requirement: R-11.A.08-M	**Responsible:** VK	**Execution date:** 26.03.2012
Document number:	**Test type:** SW measurement	**Test number:**1
Requirement description: Gripper arms shall withstand 2 812 500 cycles.		
TEST		
Expected results The gripper arm fails to survive.		
Actual results: To perform fatigue analysis it is necessary to first perform a static stress analysis. SolidWorks simulation analysis could not be performed because it was a dynamic analysis with too much deformation.		
INFORMATION		
Number of errors: 1		
Error description: - SolidWorks simulation software crash because of the large deformation of the part.		
Improvements: - Some other software could be more appropriate for this analysis.		
Approved: No		

T-11.A.79-M GRIPPER ARM STRENGTH FEM		
Traceability requirement: R-11.A.69-M	**Responsible:** VK	**Execution date:** 23.05.2012
Document number:	**Test type:** SW measurement	**Test number:**1
Requirement description: The gripper arm shall withstand the bend stresses that occur.		
TEST		
Expected results Gripper arm withstands the stresses that occur.		
Actual results: SolidWorks simulation analysis could not be performed because it was a dynamic analysis with too much deformation.		
INFORMATION		
Number of errors: 1		
Error description: - SolidWorks simulation software crash because of the large deformation of the part.		
Improvements: - Some other software could be more appropriate for this analysis.		
Approved: No		

T-11.A.80-M GRIPPER ARM CROSS SECTION		
Traceability requirement: R-11.A.70-M	**Responsible:** VK	**Execution date:** 26.03.2012
Document number:	**Test type:** SW measurement	**Test number:**1
Requirement description: Cross section of the gripper arm shall be 2,5mm ∗ 0.2mm with 14.4mm as radius.		
TEST		
Expected results: Cross section of the gripper arm is measured by SolidWorks measurement tool to be 2,5mm ∗ 0.2mm with 14.4mm as radius.		
Actual results: The actual results of the cross section of the gripper arm is measured by a SolidWorks measurement tool to be 2,5mm ∗ 0.2mm with 14.4mm as radius.		
INFORMATION		
Number of errors: 0		
Error description: No errors		
Improvements: No improvements		
Approved: Yes		

T-11.A.81-M GRIPPER ARM FIXING POINTS MEASURE (SW)		
Traceability requirement: R-11.A.71-M	**Responsible:** VK	**Execution date:** 26.03.2012
Document number:	**Test type:** SW measurement	**Test number:**1
Requirement description: The gripper arm shall contain fixing points that matches fixing points for the gripper and feeding mechanism.		
TEST		
Expected results: Fixing points matches each other.		
Actual results: By looking on an assembly of the gripper arm together with gripper and feeding mechanism in SolidWorks it shows that it is containing attachment points that matches gripper, but not for the feeding mechanism because current solution does not requires it. There is no point with attachment between gripper arm and feeding mechanism.		
INFORMATION		
Number of errors: 1		
Error description: - There are a not attachment point that matches feeding mechanism.		
Improvements: - No improvements. There is no point with attachment between gripper arm and feeding mechanism.		
Approved: No		

T-11.A.82-M GRIPPER ARM FIXING POINTS MEASURE		
Traceability requirement: R-11.A.71-M	**Responsible:** VK	**Execution date:** 24.05.2012
Document number:	**Test type:** Physical measurement	**Test number:**1
Requirement description: The gripper arm shall contain fixing points that match fixing points for the gripper.		
TEST		
Expected results: Fixing points matches each other.		
Actual results: The gripper arm is containing attachment points that matches the gripper, but not for the feeding mechanism because current solution does not requires it. Attachment holes can also easily be added to the gripper arm by drilling it.		
INFORMATION		
Number of errors: 1		
Error description: - There are a not attachment point that matches feeding mechanism.		
Improvements: - No improvements. There is no point with attachment between gripper arm and feeding mechanism.		
Approved: No		

T-12.A.16-EM FEEDING SYSTEM LIFE TIME FEM

Traceability requirement: R-10.A.01-M	**Responsible:** VK	**Execution date:** 24.03.2012
Document number: D-03.A.31-M	**Test type:** FEM analysis	**Test number:** 1

Requirement description: Feeding system should have a lifetime of at least 1 year or 1875 working hours.

Calculation of cycles per year:
25 cycles/min ·60min = 1500 cycles/hour.
1875 working hours ·1500 cycles/hour = 2 812 500 cycles.

TEST

Expected results: None of the feeding mechanism parts fails.

Actual results:

Results from stress and fatigue analyses shows that most exposed part of the feeding system has a lifetime of at least 1 year. These results are only an approximately picture of its real life, but are good enough to conclude that the gripper will withstand the stresses that occur. The test is more described in “D-03.A.31-M” document.

INFORMATION

Number of errors: 0

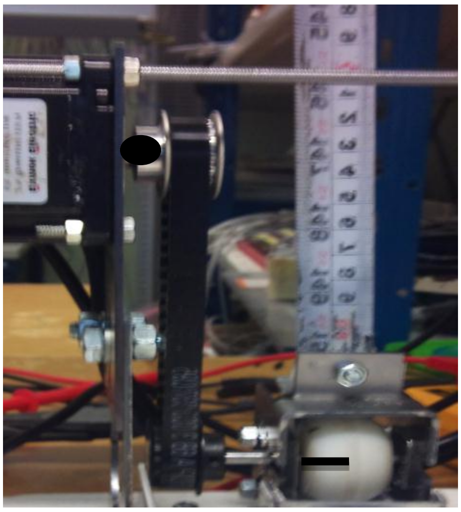
Error description:

No errors occurred

Improvements:

- More accurate S-N curve could be used to improve lifetime distribution.
- More accurate analysis where whole system is included.

Approved: Yes

T-12.A.17-EM STOP/START POINT – WITH FEEDING MECHANISM		
Traceability requirement:R-12.A.75-EM	**Responsible:** MSS and VK	**Execution date:** 14.05.2012
Document number:	**Test type:**Physical measurement	**Test number:**1
Requirement description: The feeding mechanism has to start and stop the gripper arm at the same point each cycle. An acceptable error is defined by +/- 5 mm in relation to the start/stop point. The endpoint is defined as 5 mm behind the thread at pickup, and 5 mm in front of the pulley wheel at the start point.		
TEST		
Expected results: The gripper stops within +/- 5 mm each cycle.		
Actual results: The gripper didn't meet the requirement at all. The gripper overshoots and undershoots the target greatly, more than 4 cm measured at most.		
INFORMATION		
Number of errors:2		
Error description: **1:** Sometimes the pulley wheel slipped and this means that the motor and the gripper arm isn't in synchronization. The number of pulse the motor has passed doesn't equal to the distance of the gripper arm. In order to check if the motor is regulated correctly and rule out the possibility of slip between the arm and the pulley wheel, the motor and the pulley wheel is marked with a black line. This way, if the gripper didn't returned to correct position; we could check if the reason is a friction problem or a regulating problem, Figure 1 illustrates these markings:  Figure 1: Markings on module 12		

The markings returned to same position every time. The conclusion is therefore that this is a friction problem.

2: The new fitted guidance rubbed against the gripper arm. This was made from aluminum, since the measuring tape was made of steel this cause a lot of friction when the two edges met. This created so much friction that the pulley wheel slipped. The edges are shown in Figure 2.

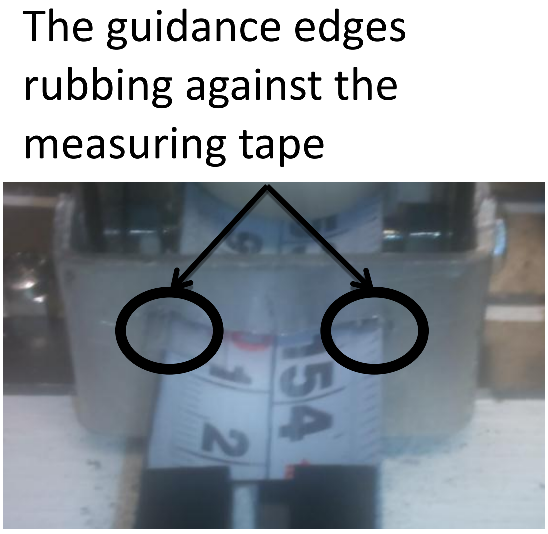


Figure 2: Guidance edges

Improvements:

- Although the regulating algorithm seems to work, there are many variables that could corrupt the regulation. In order to make the regulation less error prone the group will suggest the use of a sensor to mark a start position; this will give the regulation a fixed starting point. If slip occurs then, this will only result in the gripper moving to short of its endpoint.
- Adjusting the pressure between the pulley wheel and the free wheels might improve friction
- Changing the guidance contact material might help with the friction problems.

Approved: Not approved

T-12.A.17-EM STOP/START POINT – WITH FEEDING MECHANISM

Traceability requirement: R-12.A.75-EM	**Responsible:** MSS and VK	**Execution date:** 15.05.2012
Document number:	**Test type:** Physical measurement	**Test number:** 2

Requirement description: The feeding mechanism has to start and stop the gripper arm at the same point each cycle. An acceptable error is defined by +/- 5 mm in relation to the start/stop point.
The endpoint is defined as 5 mm behind the thread at pickup, and 5 mm in front of the pulley wheel at the start point.

TEST

Expected results: The gripper stops within +/- 5 mm each cycle.

Actual results: The gripper endpoint is slowly moving backwards, towards the start point. After 30 cycles the endpoint has moved backwards approximately 1,5 cm.

INFORMATION

Number of errors: 2

- The same check as in test 1 was done. The markings stayed in the same position, but the gripper and gripper arm didn't return to the same position. The conclusion was that there still were problems with the grip between the pulley wheel and gripper arm and with the guidance.

Improvements:

- Further adjustment to the guidance or solution is needed
- A position sensor was installed:

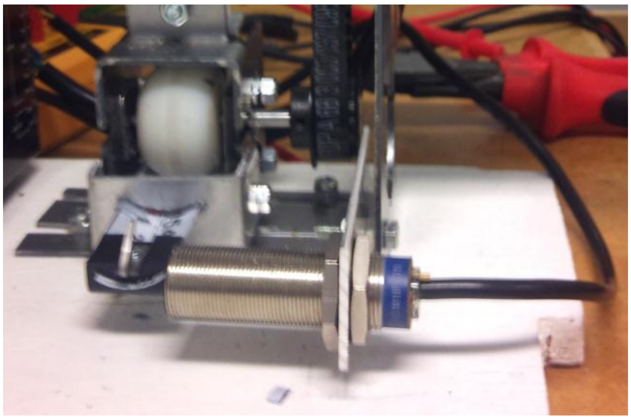


Figure 3: Sensor place in front of gripper

Approved: Not approved

T-12.A.17-EM STOP/START POINT – WITH FEEDING MECHANISM

Traceability requirement: R-12.B.75-EM	**Responsible:** MSS	**Execution date:** 17.05.2012
Document number:	**Test type:** Physical measurement	**Test number:** 3

Requirement description: The feeding mechanism has to start and stop the gripper arm at the same point each cycle. An acceptable error is defined by +/- 5 mm in relation to the start/stop point.
The endpoint is defined as 5 mm behind the thread at pickup, and 5 mm in front of the pulley wheel at the start point.

TEST

Expected results: The gripper stops within +/- 5 mm each cycle.

Actual results:

The system where set to run 200 cycles. A camera filmed the endpoint area and the film was viewed at half speed. Every time the gripper arm stopped at the endpoint, the filmed was stopped and the stop point where compare to still pictures taken of the outer stop points. The film can be found in Attachments -> Test_VideAndPics.

The most forward position of the gripper is illustrated in Figure 4.

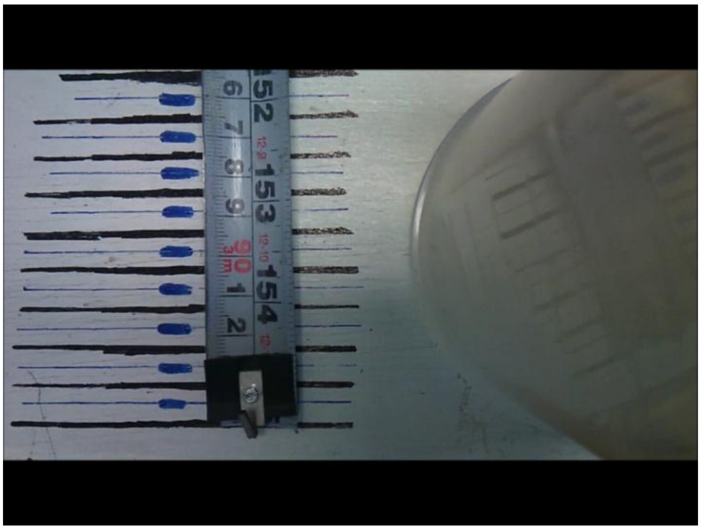


Figure 4: Gripper most forward position

The most rear position of the gripper arm is illustrated in Figure 5

Figure 5: Gripper most rear position

The distance between the black lines are 10 mm. The distance between the blue and black line are 5 mm.

In Figure 6 the difference between the most rear and forward position is more than 10 mm. Most of the time the gripper kept within the requirements.

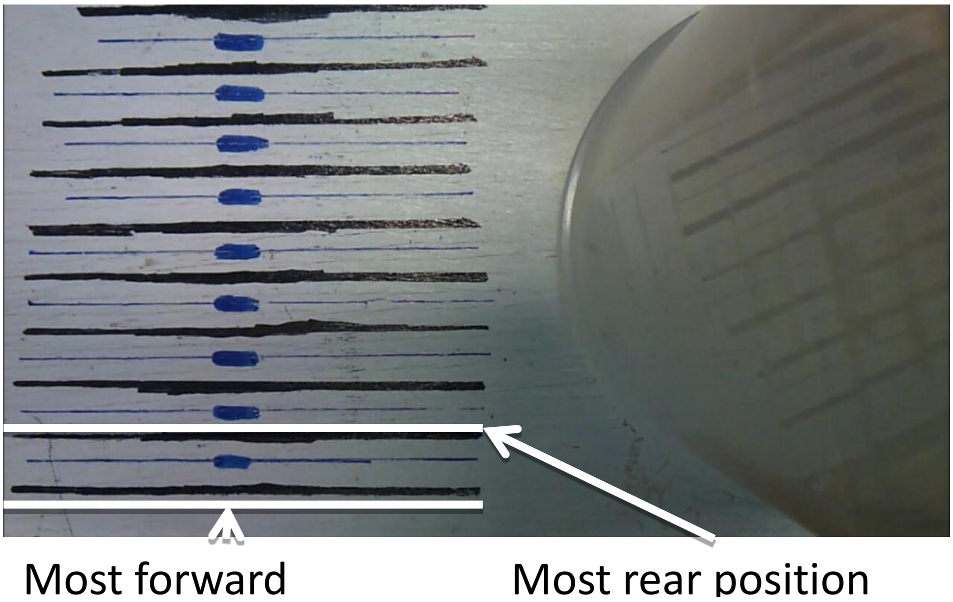


Figure 6: Difference between rear and forward

INFORMATION

Number of errors: 2

Error description: - The gripper arm cracked after approximately 150 cycles. There are still issues with the feeding mechanism, these needs to be improved before performing another similar test. - With the difference more than 10 mm, the requirement was not met.
Improvements: - Solving the problems with the feeding mechanism would improve the precision of the gripper. In addition to slip between the pulley wheel and the gripper arm, the arm is also moving sideways. - Considering a redefinition of the requirement - Change the control algorithm for the motor.
Approved: Not approved

T-12.A.18-EM TRAVELSPEED – WITH FEEDING MECHANISM		
Traceability requirement: R-12.C.76-E	**Responsible:** MSS	**Execution date:** 17.05.2012
Document number:	**Test type:** Physical measurement	**Test number:** 2
Requirement description: The feeding mechanism has to propel the gripper and gripper arm across the shed and back again within 1 second. The acceleration and top speed has to be calculated accordingly to meet this requirement.		
TEST		
Expected results: The average travel time for one cycle is < 1 second.		
Actual results: The gripper completed the cycle in less than a second, in Attachments->Test video and pics, the film "travelspeed_1second" can be viewed. This film last for 1 second, showing the gripper complete one cycle.		
INFORMATION		
Number of errors: 0		
Error description:		
Improvements:		
Approved: Approved		

T-12.A.19-M STRENGTH		
Traceability requirement: R-12.A.53-M	**Responsible:** VK	**Execution date:** 24.03.2012
Document number: D-03.A.31-M	**Test type:** SW measurement	**Test number:**1
Requirement description: The feeding mechanism for the gripper arm shall withstand the stresses that occur when the system stops suddenly or power loss.		
TEST		
Expected results: The feeding system withstands the stresses that occur when the system stops.		
Actual results: Results from stress analysis shows that most exposed part of the feeding mechanism withstands stresses that occur during suddenly stop of the system. The test is more described in "D-03.A.31-M" document. These results are only an approximately picture of real situation, but are good enough to conclude that the system will withstand the stresses that occur.		
INFORMATION		
Number of errors: 0		
Error description:		
Improvements: - More complex simulation software could perform study where the whole system is used.		
Approved: Yes		

T-12.A.83-M ADJUSTMENT OF FREE WHEELS MEASURE (SW)		
Traceability requirement: R-12.A.72-M	**Responsible:** VK	**Execution date:** 23.03.2012
Document number:	**Test type:** SW measurement	**Test number:**1
Requirement description: Free wheels (support wheels) around pulley wheel for the gripper arm shall be adjustable in the direction of pulley wheels centre. Adjustable range of minimum 3mm.		
TEST		
Expected results: Aadjustable range of free wheels is at least 3 mm.		
Actual results: By measuring assembly of feeding mechanism with SolidWorks measurement tool it shows that adjustable range of free wheels is at least 10 mm.		
INFORMATION		
Number of errors: 0		
Error description: No errors		
Improvements: No improvements.		
Approved: Yes		

T-12.A.84-M ADJUSTMENT OF FREE WHEELS MEASURE		
Traceability requirement: R-12.A.72-M	**Responsible:** VK	**Execution date:** 26.05.2012
Document number:	**Test type:** Physical measurement	**Test number:**1
Requirement description: Free wheels (support wheels) around pulley wheel for the gripper arm shall be adjustable in the direction of pulley wheels centre. Adjustable range of minimum 3mm.		
TEST		
Expected results: Adjustable range of free wheels is at least 3 mm.		
Actual results: Adjustable range of free wheels is measured by a calliper and shows to be at least 10 mm. The same result as on the CAD drawings.		
INFORMATION		
Number of errors: 0		
Error description: No errors		
Improvements: No improvements.		
Approved: Yes		

T-12.A.85-M FEEDING MECHANISM ADJUSTMENT MEASURE (SW)		
Traceability requirement: R-12.A.73-M	**Responsible:** VK	**Execution date:** 23.03.2012
Document number:	**Test type:** SW measurement	**Test number:**1
Requirement description: The whole feeding mechanism shall be adjustable in x, y and z direction. Adjustable range of minimum 10 in each direction mm.		
TEST		
Expected results: Adjustable range of the feeding mechanism is at least 10 mm.		
Actual results: By looking on assembly of the feeding mechanism in SolidWorks it shows that adjustable range of the feeding mechanism is at least 10 mm in two directions. The last direction is not available because of the limited space on actual TC-2.		
INFORMATION		
Number of errors: 0		
Error description: No errors		
Improvements: No improvements.		
Approved: Yes		

T-12.A.86-M FEEDING MECHANISM ADJUSTMENT MEASURE		
Traceability requirement: R-12.A.73-M	**Responsible:** VK	**Execution date:** 26.05.2012
Document number:	**Test type:** Physical measurement	**Test number:**1
Requirement description: The whole feeding mechanism shall be adjustable in x, y and z direction. Adjustable range of minimum 10 in each direction mm.		
TEST		
Expected results: Adjustable range of the feeding mechanism is at least 10 mm.		
Actual results: The actual result of the adjustable range of the feeding mechanism is at least 10 mm in two directions as in SW test. The last direction is not available.		
INFORMATION		
Number of errors: 0		
Error description: No errors		
Improvements: No improvements.		
Approved: Yes		

T-12.A.96-EM STOP/START POINT – ME060102

Traceability requirement:R-12.B.75-EM	**Responsible:** MSS	**Execution date:** 04.04.2012
	Test type: Physical measurement	**Test number:**1

Requirement description: The feeding mechanism has to start and stop the gripper arm at the same point each cycle. An acceptable error is defined by +/- 5 mm in relation to the start/stop point.
The endpoint is defined as 5 mm behind the thread at pickup, and 5 mm in front of the pulley wheel at the start point.

TEST

Expected results: The gripper stops within +/- 5 mm each cycle.

Actual results:

The motor cycle were performed continuously for half an hour, the motor always returned to the same point.

The motor returned to the marked point every time, proving that is possible to control the motor to the exact start point again. Given the speeds do not exceed the minimum setting at each endpoint.

INFORMATION

Number of errors:1

Error description:

- Some changes to the algorithm were necessary in order to make the motor stop at the same point each cycle. In order to make the motor stop in less than one pulse, the speed right before stopping have to be its lowest level (approximately 0,2 V). This was corrected during the test.

Improvements:

- The idle function has to be redefined when load is added.

Approved: Approved

T-12.A.97-EM TRAVELSPEED – ME060102		
Traceability requirement: R-12.C.77-EM	**Responsible:** MSS	**Execution date:** 04.04.2012
Document number:	**Test type:**Physical measurement	**Test number:**1
Requirement description: The feeding mechanism has to propel the gripper and gripper arm across the shed and back again within 1 second. The acceleration and top speed has to be calculated accordingly to meet this requirement.		
TEST		
Expected results: The average travel time for one cycle is more than 1 second.		
Actual results: The motor cycle were performed continuously for half an hour, the motor always returned to the same point. Each cycle had a travel time of about 4-5 seconds. Any more precise measurement was considered as important, since the spent time was far away from the meeting the requirement.		
INFORMATION		
Number of errors:1		
Error description: - The slow travelling time didn't come from the motor being weak, but because it had no resistance when idling down. No forces are working against the motor rotating direction, this limit the motors top speed greatly. Almost immediately after accelerating the motor has to start idle down. If this isn't done, the difference between the set speed reference and actually speed becomes too large and the PI regulator in the motor cuts the current completely. This is very time consuming, and this alone cost approximately on e second.		
Improvements: - Connecting the motor to the feeding mechanism could result in faster deceleration when the motor is idling down. This could also lead to more problems, more mass in movement leads to a longer stopping time. - In order to have a higher speed at each endpoint, the brake function should be used. This will stopped the gripper and gripper arm much faster.		
Approved: Not approved		

T-14.A.90-E VOLTAGE REGULATOR SPECIFICATIONS - L7812ACV

Traceability requirement: R-14.A.78-E	**Responsible:** MSS	**Execution date:** 01.05.2012
Document number:	**Test type:** Physical measurement	**Test number:** 1

Requirement description: The following specification needs to be satisfied:

- Voltage in : 24 V +/- 0,5 V
- Voltage out: 12 V +/-0,3 V
- The voltage regulator have to deliver enough effect to power the 12 V circuit

TEST

Expected results: The regulator will deliver 12 V and function on 24 V supply with load that draws 0,8 ampere..

Actual results:

Tests were done with multiple resistance values and the load was at least active for 5 minutes:

80 Ohm: Lowest registered voltage: 11,77 V, stable voltage

70 Ohm: Lowest registered voltage: 9,34 V, Normally 11,56 but sometime it dropped.

100 Ohm: Lowest registered voltage: 11,84, stable voltage.

The Voltage output was satisfied, within +/-0,3 V of 12 V.

And the supply voltage was 24 Volts.

This will give a maximum output current: 12/80 =0,15 A = 150 mA. Exceeding this will create a much bigger voltage drop and heat problems.

Since the Voltage regulator seemed to perform at best when the resistance was 100 Ohm, we will not recommend drawing more than 12/100 = 120 mA. This to avoid any heat problems or unstable voltages, it's not likely that we need to draw more than this at this point.

INFORMATION

Number of errors: 2

Error description:

1: The circuit mounted without the conductors, resulting in total failure. Conductors were mounted right away.

2: The voltage regulator couldn’t handle 0,4 Ampere.

Improvements:

- Heat sink can be mounted, an aluminum plate will probably help or we can by a heat sink.
- A resistor in series with the voltage regulator would also help, reducing the voltage drop over the regulator. This circuit is illustrated in Figure 7:

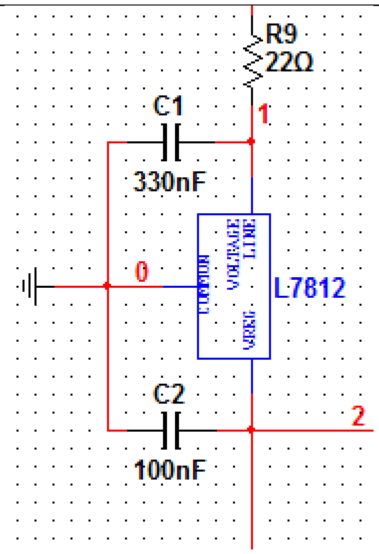


Figure 7: Voltage regulator with effect resistor

- Proper calculations in the technology document have to be developed.

Approved: Not approved

T-14.A.90-E VOLTAGE REGULATOR SPECIFICATIONS - L7812ACV		
Traceability requirement: R-14.A.78-E	**Responsible:** MSS	**Execution date:** 09.05.2012
Document number:	**Test type:** Physical measurement	**Test number:** 2

Requirement description: The following specification needs to be satisfied:

- Voltage in : 24 V +/- 0,5 V
- Voltage out: 12 V +/-0,3 V
- The voltage regulator have to deliver enough effect to power the 12 V circuit

TEST

Expected results: The regulator will deliver 12 V and function on 24 V supply with load that draws 0,4 ampere..

Actual results:

Tests were done with multiple resistance values and the load was at least active for 5 minutes:

40 Ohm:

Lowest registered regulator output voltage: 11.73 V, stable voltage.

$\frac{11,74\ V}{40\ Ohm} = 0,2943\ A$ maximum output current current

Voltage drop over resistor: $6,75\ V => P = 6,75\ V * 0,2943 \approx 2\ W$

30 Ohm:

Lowest registered regulator output voltage: 11.73 V, stable voltage.

$\frac{11,84\ V}{30\ Ohm} = 0,394\ A$ maximum output current current

Voltage drop over resistor: $9,44\ V => P = 9,44\ V * 0,394\ A \approx 3,72\ W$

The Voltage output was satisfied, within +/-0,3 V of 12 V.

And the supply voltage was 24 Volts.

The reason for the more stabile voltage output at higher loads is the result of the voltage drop over the voltage regulator. At lower loads the voltage drop over the effect resistor is lower and the voltage drop over regulator is higher, this mean that the power dissipation for the regulator needs to much higher.

NOTE:

The effect resistor gets extremely hot, if this amount of current is going to be drawn for the regulator circuit and the regulator is mounted on breadboard, it must be switched off when not observed.

INFORMATION

Number of errors: 0

Error description:

Improvements:

- Heat sink can be mounted to help with power dissipation at lower loads - The regulator circuit should be mounted on a better suitable platform than a breadboard, to reduce risk of heat damages. A PCB will work better as heat conductor.
Approved: Not approved

T-14.A.92-E VOLTAGE FOLLOWER SPECIFICATIONS – CA3130		
Traceability requirement: R-14.A.81-E	**Responsible:** MSS	**Execution date:** 01.05.2012
Document number:	**Test type:** Physical measurement	**Test number:** 1
Requirement description: The following specification needs to be satisfied: - Got to operate on voltage supply 12 V +/- 1 Volts - The operational amplifier has to support rail to rail output. - Has to response as fast as the DAC. The output voltage has to change as fast as the output voltage of DAC.		
TEST		
Expected results: The voltage output is the same as the voltage input on the inverting input.		
Actual results: The output always stayed within +/- 0.1 V.		
INFORMATION		
Number of errors: 0		
Error description: No errors occurred		
Improvements:		
Approved: Approved.		

T-14.A.93-E DAC SPECIFICATION – AD558

Traceability requirement: R-14.A.83-E	**Responsible:** MSS	**Execution date:** 01.05.2012
Document number:	**Test type:** Physical measurement	**Test number:** 1

Requirement description: The following specification needs to be satisfied:

- The DAC have to be a 8 bit parallel DAC
- Got to operate on voltage supply 12 V +/- 1 Volts
- The DAC have to deliver a voltage output in the range of 0 -5 V +/- 0,1 Volt.

TEST

Expected results: The voltage output is the same as the voltage input

Actual results:

Connections on AD558:

FUNCTIONAL BLOCK DIAGRAM

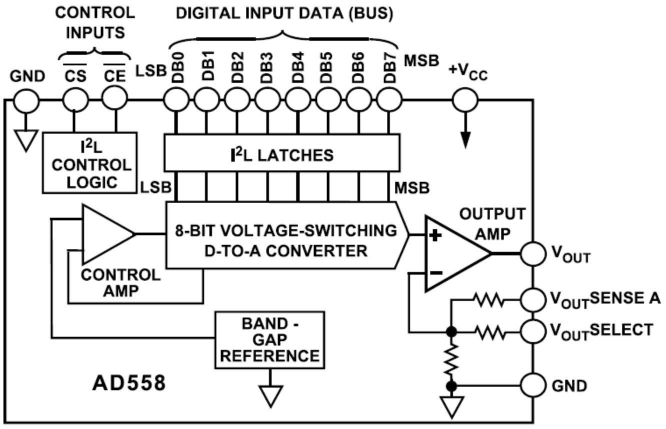
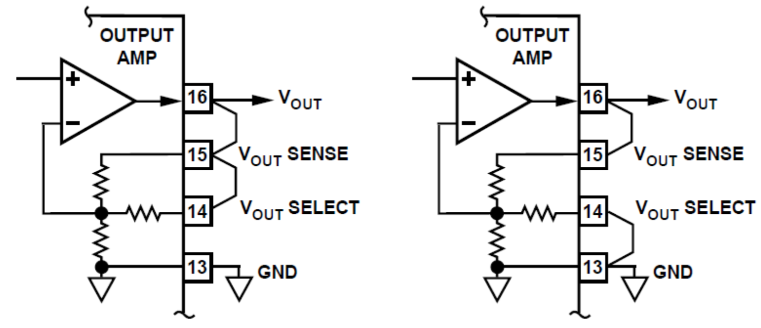


Figure 8: Functional block diagram, AD558

The ATmega128RFA1 were used by other group member, so the NI-USB 6008 was used in test. The main difference is that the logical outputs of the NI USB-6008 is high = 5V. Since the AD558 defines a high input as >2 Volt, shouldn't we get any surprises when switching to the ATmega128RFA1.

The inputs DB0- DB7 were connected to Line 0, ports 0 -7 on the NI USB-6008. The CE was connected to Line 1, port 0, CS was grounded.

Voltage supply was 12 V, and the range were wired so that the output ranged from 0 – 2,56 V, illustrated in Figure 9.



a. 0 V to 2.56 V Output Range b. 0 V to 10 V Output Range
Figure 3. Connection Diagrams

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Figure 9: Range connection, AD558

With CE low (putting the DAC in transparent mode, inputs = output):

Port 0 were set at different values, the output voltage were measured and controlled according to specifications.

Port 0 = 0b00001111 => Voltage out = 0,21 V

Port 0 = 0b11110000 => Voltage out = 2,41 V

Port 0 = 0b00111100 => Voltage out = 0,59 V

All of the output were +/-0,1 of the input values.

INFORMATION

Number of errors:1

Error description:
The planned circuit didn’t work because of incorrect interpretation of the component datasheet.

Improvements:
In order to get an output voltage of 5 V an operational amplifier has to be added to gain the voltage to 5 V, or the DAC has to be set at 10 V and then only us half of its range.

Approved: Approved

T-14.A.98-E VOLTAGE AMPLIFIER SPECIFICATIONS – CA3130

<table>
<tr><td>Traceability requirement:R-14.A.81-E</td><td>Responsible: MSS</td><td>Execution date: 01.05.2012</td></tr>
<tr><td>Document number:</td><td>Test type:Physical measurement</td><td>Test number:1</td></tr>
<tr><td colspan="3">Requirement description: The amplifier specification needs to be satisfied:
- Got to operate on voltage supply 12 V +/- 1 Volts
- The operational amplifier has to support rail to rail output.
- The output voltage has to change as fast as or faster than the output voltage of DAC.
- The gain of the amplifier has to be $\frac{4,6\ V}{2,56\ V}$ = 1,8 +/- 0,1</td></tr>
<tr><td colspan="3">TEST</td></tr>
<tr><td colspan="3">Expected results: The non inverting input voltage is gained by 1,8 +/ 0,1</td></tr>
<tr><td colspan="3">Actual results:
The measured output voltage was 60 mV and 4,7 V.</td></tr>
<tr><td colspan="3">INFORMATION</td></tr>
<tr><td colspan="3">Number of errors:0</td></tr>
<tr><td colspan="3">Error description:
No errors occurred</td></tr>
<tr><td colspan="3">Improvements:
To ensure that the voltage amplifier doesn’t reduce performance of the DAC, a test with an oscilloscope have to be done to determine the actual slew rat.</td></tr>
<tr><td colspan="3">Approved: Approved.</td></tr>
</table>

T-20.A.40-EM LIFETIME

Traceability requirement: R-20.A.18-EM	**Responsible:** AV	**Execution date:** 09.05.2012
Document number: D-03.A.31-M	**Test type:** FEM analysis	**Test number:** 1

Requirement description: The thread selection system shall have a lifetime of at least 5 years or 9375 working hours.

TEST

Expected results: None of the components of the thread selection system fails

Actual results:

The shaft were tested for fatigue in SolidWorks simulation. The results from the fatigue analysis showed that the shaft will withstand 9375 working hours.

INFORMATION

Number of errors: 0

Error description:

No errors occurred

Improvements:

More accurate S-N curve could be used to improve lifetime distribution.

Approved: Approved

T-20.A.64-EM COMPABILITY OF DIFFERENT THREADS		
Traceability requirement: R-20.A.17-EM	**Responsible:** AV	**Execution date:** 03.05.2012
Document number:	**Test type:** Full System test	**Test number:**1
Requirement description: The system will be able to handle all types of threads as can be used on the TC2.		
TEST		
Expected results: It passes, because there is not much difference in the threads.		
Actual results: The system were tested with all four different threads given from Tronrud Engineering. The thread selection were tested in a system integration test. We tested with 100 cycles where 2 errors related to the handling of threads. The holder were not able to hold the thread and the thread snapped after 80 cycles. The problems occur due to friction. The friction problems comes from three different modules: 1: **Thread holding system**: The cylindrical spools were not tested in this cycle run due to high friction. The conical spools were used which have much less friction. There were some errors with the one conical spool this is due to the spool up of the spool. 2: **Thread selection:** Friction occurs from edges around the casing this is because the prototype does not have guiding for the thread. Friction from the "hole for thread" in the arm is also a problem. 3: **Thread feeding:** The edges on the gripper also causes friction. We were able to brush down the edges a bit which help a lot. Still some friction problems.		
INFORMATION		
Number of errors: 2		
Error description: Friction		
Improvements: - Only use conical spools in holding system. - Use guiding from holding system to selection system for the thread. - Use fillets in the "hole for thread" - Fillets around gripper edges.		
Approved: Not approved		

T-20.A.75-EM POSITION ERROR		
Traceability requirement: R-20.A.65-EM	**Responsible:** AV/IYE	**Execution date:** 03.05.2012
Document number:	**Test type:** Module test	**Test number:**1
Requirement description: The operation arm shall place the thread so that the gripper can pick it up		
TEST		
Expected results: The arms moves as planned.		
Actual results: The arm moved as thought		
INFORMATION		
Number of errors: 0		
Error description:		
Improvements: Can be optimized more with relation to time (minimize the distance the arm has to move, giving the system more speed)		
Approved: Approved		

T-20.A.77-M SIZE OF THREAD SELECTION		
Traceability requirement:R-20.A.67-EM	**Responsible:** AV	**Execution date:** 03.05.2012
Document number:	**Test type:** Module test	**Test number:**1
Requirement description: The module size should not exceed the limitations given by Tronrud Engineering		
TEST		
Expected results: The module fits		
Actual results: The module did not fit		
INFORMATION		
Number of errors: 1		
Error description: This module is the backup solution and did not fitted the space limitations given by Tronrud Engineering.		
Improvements: The original design did fit the TC2. This idea was discarded due to expensive components.		
Approved: No		

T-22.A.48-E	THREAD FEEDING NOTIFY - MODULE	
Traceability requirement: R-22.A.48-E	**Responsible:** EN	**Execution date:** 30.04.2012
Document number:	**Test type:** Module	**Test number:**1
Requirement description: The gripper shall reduce its speed if a thread are failed to be delivered or snapped, and keep this reduced speed until it reaches its initial position.		
TEST		
Expected results: It does not reduce its speed because the system does not detect a cut thread.		
Actual results: We have got a thread sensor specially designed to detect movement of a weft thread. With this sensor, we did not have any trouble to detect the movement of the threads. The gripper reduces its speed if the sensor does not detect any movements of the thread.		
INFORMATION		
Number of errors:0		
Error description:		
Improvements: Do tests with the full system.		
Approved: Yes		

T-22.A.48-E THREAD FEEDING NOTIFY - INTEGRATION		
Traceability requirement: R-22.A.87-E	**Responsible:** AS/EN	**Execution date:** 22.05.2012
Document number:	**Test type:** Prototype	**Test number:**2
Requirement description: The gripper shall reduce its speed if a thread are failed to be delivered or snapped, and keep this reduced speed until it reaches its initial position.		
TEST		
Expected results: The gripper will reduce its speed when the gripper does not grab the thread.		
Actual results: The system did reduce the speed when it did not grab any threads.		
INFORMATION		
Number of errors: 0		
Error description:		
Improvements:		
Approved: Yes		

T-22.A.70-M THREAD FEEDING BUFFER		
Traceability requirement: R-22.A.60-M	**Responsible:** EN, AS	**Execution date:** 22.05.2012
Document number:	**Test type:** Module test	**Test number:**1
Requirement description: The thread feeding path shall be longer than the pick itself.		
TEST		
Expected results: It is longer than the pick.		
Actual results: The path length is 1,21 meter, and the a pick will be less than a meter.		
INFORMATION		
Number of errors:0		
Error description:		
Improvements:		
Approved: Yes		

T-22.A.94-E HALT ON MULTIPLE THREADS		
Traceability requirement: R-22.A.86-E	**Responsible:** AS, EN	**Execution date:** 22.05.2012
Document number:	**Test type:** Integration test	**Test number:**1
Requirement description: The gripper shall halt within 10cm if multiple threads are pulled. The user will then have to press SW0-button to get the gripper back to its initial position.		
TEST		
Expected results: The gripper halts immediately when the gripper pulls two threads. When SW0 is pulled, the		
Actual results: The gripper had to pull the thread 5.5cm before the system registered that two threads where pulled.		
INFORMATION		
Number of errors: 0		
Error description:		
Improvements:		
Approved: Yes		

MODULE 23: THREAD HOLDING SYSTEM

T-23.A.51-M	SPOOL VARIATION	
Traceability requirement: R-23.A.31-M	**Responsible:** AS	**Execution date:** 21.02.2012
Document number:	**Test type:** Module test	**Test number:** 1
Requirement description: The holding system shall be able to hold conical spools.		
TEST		
Expected results: Almost all types fit		
Actual results: All conical spools fit the system, as long as the spools have an inside diameter of more than 6mm and are smaller than 15cm high and 12cm wide.		
INFORMATION		
Number of errors: 0		
Error description: N/A		
Improvements: Could test with many other spools		
Approved: Yes		

T-23.A.52-M CAPACITY		
Traceability requirement: R-23.A.26-M	**Responsible:** AS	**Execution date:** 21.02.2012
Document number:	**Test type:** Module test	**Test number:** 1
Requirement description: The thread holding system must be able to hold 8 spools**.**		
TEST		
Expected results: All spools fit		
Actual results: Only 4 spools could be mounted to the thread holding system.		
INFORMATION		
Number of errors: 1		
Error description: We only tested one half of the designed thread holding system, and it took 4 spools. If we tested the whole system, it had accepted 8 spools.		
Improvements: Test the whole thread holding system, and not just one half.		
Approved: No		

T-23.A.53-E NOTIFY		
Traceability requirement: R-23.A.28-E	**Responsible:** AS, EN	**Execution date:** 22.05.2012
Document number:	**Test type:** Module/prototype test	**Test number:** 1
Requirement description: Thread holding system notify user when spools are becoming empty.		
TEST		
Expected results: The system will understand when a spool is empty, and will result in reduced speed of the gripper arm. This reduced speed is the notification for the user.		
Actual results: The gripper reduced the speed when it did not pull any threads. It did not pull any thread because the spool was empty.		
INFORMATION		
Number of errors: 0		
Error description: N/A		
Improvements: N/A		
Approved: Yes		

T-23.A.68-M THREAD RESISTANCE - STRAIGHT OFF CONICAL SPOOL		
Traceability requirement:R-23.A.59-M	**Responsible:** EN, AS	**Execution date:** 06.02.2012
Document number:	**Test type:** Test of concept	**Test number:**1
Requirement description: The threads must be easily pulled off the spools. The spools are vertical and not rotating.		
TEST		
Expected results: The thread on conical spools will easily be pulled off.		
Actual results: There was no problems to get the thread of the two conical spools.		
INFORMATION		
Number of errors:0		
Error description:		
Improvements:		
Approved: Yes		

T-23.A.99-M THREAD RESISTANCE - STRAIGHT OFF CYLINDRICAL SPOOL		
Traceability requirement:R-23.A.59-M	**Responsible:** EN, AS	**Execution date:** 06.02.2012
Document number:	**Test type:** Test of concept	**Test number:**1
Requirement description: The threads must be easily pulled off the spools. The spools are vertical and not rotating.		
TEST		
Expected results: The thread on cylindrical spools will be a bit tricky to pull off because the angle from the outer circumference of the spool, and up to the center hole, is negative. This will create a lot of friction on the loose thread on its way to the center hole.		
Actual results: It was a bit tricky to pull the thread straight upward of the cylindrical spool. The thread was stuck in itself, especially at the top of the spool.		
INFORMATION		
Number of errors:0		
Error description: Problems with the thread. It's not loose enough, so it will be problematic for the gripper to pull the thread smoothly.		
Improvements: Add a rotational arm at the top of the spool. This will give the thread an outgoing angle, and hopefully it will be less friction this way.		
Approved: No		

T-23.A.100-M THREAD RESISTANCE - CYLINDRICAL SPOOL WITH ARM		
Traceability requirement:R-23.A.59-M	**Responsible:** EN, AS	**Execution date:** 06.02.2012
Document number:	**Test type:** Test of concept	**Test number:** 1
Requirement description: The threads must be easily pulled off the spools. The spools are vertical and not rotating.		
TEST		
Expected results: With this rotating arm, we will get a positive angle of the thread off the spool. This will cause the thread to go more easy off the spool.		
Actual results: It was now much easier to pull of the thread from cylindrical spool. With slow speed we did not detect any problems, but when the thread were pulled fast off the spool, the arm started to spin uncontrolled. That resulted in a stuck thread, which caused problems for the next pick.		
INFORMATION		
Number of errors:1		
Error description: When we pulled the thread fast, the thread got stuck.		
Improvements: Try to use a big "hat" on the top of the spool, instead of a rotating arm. This will remove all the moment of inertia, except of the moment of inertia in the thread, and we will now hopefully get a smooth pull-off of the thread		
Approved: No		

T-23.A.101-M THREAD RESISTANCE - WITH BIG DISC		
Traceability requirement:R-23.A.59-M	**Responsible:** EN, AS	**Execution date:** 13.02.2012
Document number:	**Test type:** Test of concept	**Test number:**1
Requirement description: The threads must be easily pulled off the spools. The spools are vertical and not rotating.		
TEST		
Expected results: It will now be easier to pull out the thread on the cylindrical spool, and we have no moving part which will result in self-spinning.		
Actual results: We did immediately notice that the thread was not rotating around the disc as easy as we hoped. The angle on the outgoing thread became too high, so the upward force-component became too small.		
INFORMATION		
Number of errors:2		
Error description: Friction in the disc, and problems to spin out the thread.		
Improvements: Use a smaller disc, so we get more out of the up-going force. The disc must of course be wider than the diameter of the spool.		
Approved: No		

T-23.A.102-M THREAD RESISTANCE - WITH SMALLER DISC		
Traceability requirement:R-23.A.59-M	**Responsible:** EN, AS	**Execution date:** 13.02.2012
Document number:	**Test type:** Test of concept	**Test number:**1
Requirement description: The threads must be easily pulled off the spools. The spools are vertical and not rotating.		
TEST		
Expected results: It will now be easier to pull out the thread on the cylindrical spool because we get more out of the upward force.		
Actual results: First we tried with a big cylindrical spool. This spool was almost as wide as the disc on the top. This did work perfectly. Then we tried a conical spool, and that did also worked perfectly. Then we tried a cylindrical spool which were much smaller than the first one, but with the same size of the disc. Now we got the same result as the test T-23.A.101-M.		
INFORMATION		
Number of errors: 1		
Error description: When the spool gets thinner, which will happen when the weaver has weaved for a while; the thread will start to get stuck.		
Improvements: Create a loose buffer system.		
Approved: No		

T-23.A.103-M THREAD RESISTANCE - WITH BUFFER		
Traceability requirement:R-23.A.59-M	**Responsible:** EN, AS	**Execution date:** 16.02.2012
Document number:	**Test type:** Test of concept	**Test number:**1
Requirement description: The threads must be easily pulled off the spools. The spools are vertical and not rotating.		
TEST		
Expected results: We might have problems with stuck yarn, but beside that the thread will move much more smoothly.		
Actual results: As expected. It was difficult to control the thread inside the buffer. That resulted in many different problems.		
INFORMATION		
Number of errors:2		
Error description: It was difficult to have a controlled thread laying inside the buffer, so it got stuck together. It was also å problem that the thread got "glued" to the wheels, and start spinning around them.		
Improvements: The rotating arm (T-23.A.100-M) has until now been the most successful solution, so if we can make a braking mechanism to stop the spinning arm when the gripper is no longer pulling the thread, then we might have a solution. Alternately we can reduce the pull-off speed when we are pulling thread from one of the cylindrical spools.		
Approved: No		

T-23.A.99-M THREAD RESISTANCE - CYLINDRICAL SPOOL WITH ARM		
Traceability requirement: R-23.A.59-M	**Responsible:** EN, AS	**Execution date:** 27.02.2012
Document number:	**Test type:** Cycle test	**Test number:** 2
Requirement description: The threads must be easily pulled off the spools. The spools are vertical and not rotating.		
TEST		
Expected results: With this rotating arm, we will get a positive angle of the thread off the spool. This will cause the thread to go more easy off the spool.		
Actual results: As expected, with a low speed we could pull off the thread from the cylindrical spool with the rotating arm. The low speed did not cause any problems with the rotating arm keep spinning when the thread no longer got pulled.		
INFORMATION		
Number of errors: 0		
Error description:		
Improvements: Use a clutch/break on the gripper arm. In that way it should be possible to have high speed on the gripper arm with no problems.		
Approved: Yes		

T-30.A.54-E OPERATIONAL VOLTAGE

Traceability requirement:R-30.A.44-E	**Responsible:** MSS	**Execution date:** 20.05.12
Document number:	**Test type:** Physical measurement	**Test number:**1
Requirement description: The operational voltage of the microcontroller shall be 12v or less.		
TEST		
Expected results: The voltage is not higher than 12 volt.		
Actual results: We are using an ATmega128RFA1 mounted on a STK 600. Rated operating voltage on external supply is 10 -15 V. The measured voltage on voltage supply input was 11,84 V.		
INFORMATION		
Number of errors: 0		
Error description:		
Improvements:		
Approved: Yes		

T-30.A.89-E SERIAL COMMUNICATION		
Traceability requirement:R-30.A.85-E	**Responsible:** IYE	**Execution date:** 30.04.12
Document number:	**Test type:** Communication test	**Test number:**1
Requirement description: The microcontroller shall communicate with the Faulhaber MCBL 2805 by serial on a 9600 baud rate		
TEST		
Expected results: The Faulhaber and ATmega will behave as expected. The Faulhaber will perform the primitive commands given over the serial.		
Actual results: The ATmega ran the program, but the Faulhaber didn't not respond at all		
INFORMATION		
Number of errors:1		
Error description: The serial did not work properly		
Improvements: Check cable for correct alignment of pins and use oscilloscope		
Approved: No		

T-30.A.89-M SERIAL COMMUNICATION		
Traceability requirement:R-30.A.85-E	**Responsible:** IYE	**Execution date:** 01.05.12
Document number:	**Test type:** Communication test	**Test number:**2
Requirement description: The microcontroller shall communicate with the Faulhaber MCBL 2805 by serial on a 9600 baud rate		
TEST		
Expected results: There can still be problems		
Actual results: The ATmega ran the program, but the Faulhaber didn't not respond at all		
INFORMATION		
Number of errors:1		
Error description: The serial did not work properly.		
Improvements: Adjust the prescaler for the serial on the ATmega (the scaling of the clock)		
Approved: No		

T-30.A.89-M SERIAL COMMUNICATION		
Traceability requirement: R-30.A.85-E	**Responsible:** IYE	**Execution date:** 01.05.12
Document number:	**Test type:** Communication test	**Test number:** 3
Requirement description: The microcontroller is communication with the Faulhaber MCBL2805 by serial on a 9600 baud rate.		
TEST		
Expected results: There can still be problems.		
Actual results: The serial responds to simple commands like "V500"		
INFORMATION		
Number of errors: 0		
Error description: -		
Improvements: Test with the configuration used for the system		
Approved: Yes		

T-30.A.89-M SERIAL COMMUNICATION		
Traceability requirement: R-30.A.85-E	**Responsible:** IYE	**Execution date:** 01.05.12
	Test type: Operational test	**Test number:** 4
Requirement description: The microcontroller is communication with the Faulhaber MCBL2805 by serial on a 9600 baud rate.		
TEST		
Expected results: It will work properly		
Actual results: The serial works perfectly		
INFORMATION		
Number of errors: 0		
Error description: -		
Improvements: -		
Approved: Yes		

T-30.A.95-E ANALOG COMPARATOR INPUT VOLTAGES		
Traceability requirement: R-30.A.88-E	**Responsible:** EN	**Execution date:** 07.05.12
Document number:	**Test type:** Voltage measurements	**Test number:** 1
Requirement description: The analog comparator output (ACO) shall be low when the voltage from the weft sensor is lower than the reference voltages (0.5V and 1.3V), and vice versa.		
TEST		
Expected results: We will measure the same voltage on the pins when the sensor and voltage references are connected, as we did while these are not connected to the pin.		
Actual results: We did not measured the "correct" voltage on PE2 - the voltage from the weft sensor. Also, we measured 1.91V on the PE2 when it was defined as a input without pull-up. This voltage is supposed to be 0.00V.		
INFORMATION		
Number of errors: 1		
Error description: The voltage on the PE2 pin was supposed to be 0.01V when the weft sensor was connected to it. We measured 0.7V. Since 0.7V is higher than 0.5V, the ACO become high when it should have been low. We think this is because something is wrong with the STK600 or the 128RFA1.		
Improvements: Try another STK600.		
Approved: No		

T-30.A.95-E ANALOG COMPARATOR INPUT VOLTAGES - NEW STK600		
Traceability requirement: R-30.A.88-E	**Responsible:** EN	**Execution date:** 08.05.12
Document number:	**Test type:** Voltage measurements	**Test number:** 2
Requirement description: The analog comparator output (ACO) shall be low when the voltage from the weft sensor is lower than the reference voltages (0.5V and 1.3V), and vice versa.		
TEST		
Expected results: We will measure the same voltage on the pins when the sensor and voltage references are connected, as we did while these are not connected to the pin.		
Actual results: We did not measured the "correct" voltage on PE2 - the voltage from the weft sensor. Also, we measured 1.91V on the PE2 when it was defined as a input without pull-up. This voltage is supposed to be 0.00V.		
INFORMATION		
Number of errors: 1		
Error description: This gave us the exact same error. This means that the STK600 most likely is not the problem.		
Improvements: Get advice from teacher.		
Approved: No		

T-30.A.95-E ANALOG COMPARATOR INPUT VOLTAGES - ADVICE FROM TEACHER		
Traceability requirement: R-30.A.88-E	**Responsible:** EN	**Execution date:** 08.05.12
Document number:	**Test type:** Voltage measurements	**Test number:** 3
Requirement description: The analog comparator output (ACO) shall be low when the voltage from the weft sensor is lower than the reference voltages (0.5V and 1.3V), and vice versa.		
TEST		
Expected results: We will measure the same voltage on the pins when the sensor and voltage references are connected, as we did while these are not connected to the pin.		
Actual results: Nothing closer to any improvements.		
INFORMATION		
Number of errors: 2		
Error description: The meeting with our teacher gave us two possible hypothesis: • We have done something random with a random register, which overrides a function. If this is the case, this must be a register that do not reset when I upload new code to the micro controller. • There have been some damage on the microcontroller, and some of the functions are not working properly.		
Improvements: Try another 128RFA1, another STK600 and another computer to program it.		
Approved: No		

T-30.A.95-E ANALOG COMPARATOR INPUT VOLTAGES - NEW 128RFA1		
Traceability requirement: R-30.A.88-E	**Responsible:** EN	**Execution date:** 10.05.12
Document number:	**Test type:** Voltage measurements	**Test number:** 4
Requirement description: The analog comparator output (ACO) shall be low when the voltage from the weft sensor is lower than the reference voltages (0.5V and 1.3V), and vice versa.		
TEST		
Expected results: We will measure the same voltage on the pins when the sensor and voltage references are connected, as we did while these are not connected to the pin.		
Actual results: We measured 1.91V on the PE2 when it was defined as a input without pull-up. This voltage is supposed to be 0.00V.		
INFORMATION		
Number of errors: 1		
Error description: This gave us the exact same problem. This means that the 128RFA1 circuit board we used, most likely is not broken, and that the problem has nothing to do with "memorized" mess-up in any registers.		
Improvements: Get advice from AVR-support.		
Approved: No		

T-30.A.95-E ANALOG COMPARATOR INPUT VOLTAGES - AVR-SUPPORT		
Traceability requirement: R-30.A.88-E	**Responsible:** EN	**Execution date:** 17.05.12
Document number:	**Test type:** E-mail support	**Test number:** 5
Requirement description: The analog comparator output (ACO) shall be low when the voltage from the weft sensor is lower than the reference voltages (0.5V and 1.3V), and vice versa.		
TEST		
Expected results: AVR-support will give us the support we need, so that we will be able to measure the same voltage on the pins when the sensor and voltage references are connected, as we did while these are not connected to the pin.		
Actual results: The answer we got was that since the 128RFA1 is an evaluation board, AVR have mounted some LEDs to indicate transmission and reception of RF frames. These LEDs are connected to VTG_INT in series with resistors, and then directly to PE2, PE3 and PE4. They suggested us to try to remove these LEDs.		
INFORMATION		
Number of errors: 0		
Error description:.		
Improvements: Remove the LEDs soldered on the 128RFA1. This will isolate the pins on Port E from the VTG_INT source and hopefully fix the problem with current leakage.		
Approved: No		

T-30.A.95-E ANALOG COMPARATOR INPUT VOLTAGES - WITHOUT LED		
Traceability requirement:R-30.A.88-E	**Responsible:** EN	**Execution date:** 21.05.12
Document number:	**Test type:** Voltage measurements	**Test number:** 6
Requirement description: The analog comparator output (ACO) shall be low when the voltage from the weft sensor is lower than the reference voltages (0.5V and 1.3V), and vice versa.		
TEST		
Expected results: We will measure the same voltage on the pins when the sensor and voltage references are connected, as we did while these are not connected to the pin.		
Actual results: We measured 0.01V on the PE2 when it was connected to the weft sensor. This made the ACO to be low. When we pulled a thread through the weft sensor, the ACO went high.		
INFORMATION		
Number of errors: 0		
Error description:.		
Improvements:		
Approved: Yes		

T-31.A.62-E SPOOL SIZE

Traceability requirement: R-31.A.51-E	**Responsible:** EN	**Execution date:** 24.04.2012
Document number:	**Test type:** Voltage measurement	**Test number:** 1
Requirement description: There shall be sensors on each spool to warn the system when it is, or soon is, no more thread on the spool.		
TEST		
Expected results: All the sensors are mounted correctly, and the sensors are trigging, but some calibration will be likely.		
Actual results: We got this to work at the first attempt. When we connected 24V, GND and Gain sensitivity to the weft sensor, and used a pull-down resistor on the discrete current output, we got different discrete voltages depending on how mane threads we were pulling.		
INFORMATION		
Number of errors: 0		
Error description:		
Improvements: Do the same test on the full-system.		
Approved: Yes		

T-31.A.63-E DOOR SAFETY		
Traceability requirement:R-31.A.56-E	**Responsible:** EN, MSS	**Execution date:** 30.04.2012
Document number:	**Test type:** Voltage measurement	**Test number:**1
Requirement description: The system shall halt when the maintenance doors for the spools are open.		
TEST		
Expected results: All the sensors are mounted correctly, and the sensors are trigging.		
Actual results: We are simulating this sensor with a switch. Switch 2 is connected to an interrupt flag, and as soon as it is pressed, the system halts, and waits for the switch 0 (SW0)button to be pressed.		
INFORMATION		
Number of errors:0		
Error description:		
Improvements: Do the same test on the full-system.		
Approved: Yes		

T-31.A.66-E YARN SENSOR - INPUT VOLTAGE		
Traceability requirement: R-31.A.57-M	**Responsible:** EN	**Execution date:** 24.02.2012
Document number:	**Test type:** Visual test	**Test number:** 1
Requirement description: The sensor shall be turned on when 24 volt is connected.		
TEST		
Expected results: The LED-indicator will start lighting.		
Actual results: The LED-spot did not emit any light, and there were no signs of an operating system.		
INFORMATION		
Number of errors:1		
Error description: It was not possible to see any signs of life from the sensor.		
Improvements: Assume that there is no indication of an operating sensor, and try the output voltage with all the wires connected. If that does not work, send the sensor back as DOA.		
Approved: Yes, see T-31.A.67-E		

T-31.A.67-E YARN SENSOR - OUTPUT VOLTAGE		
Traceability requirement:R-31.A.58-M	**Responsible:** EN	**Execution date:** 24.02.2012
Document number:	**Test type:** Voltage measurement	**Test number:**1
Requirement description: The sensor shall give a constant output while the thread is moving, and give another voltage when the thread is not moving. It should also give an individual voltage if too many threads are moving.		
TEST		
Expected results: Some problems will occur, but we will get it to work in the end.		
Actual results: We used a 680 ohms resistor as a shunt resistor, and calculated that this would give 1,86V. When we tested, we got exactly that number, and it was nice and steady. The only problem is that we need some tension to activate it. We used 5V gain sensitivity, and 6,5V is maximum sensitivity. In other word, we will most likely be able to use this sensor.		
INFORMATION		
Number of errors:0		
Error description: N/A		
Improvements: N/A		
Approved: Yes		

T-40.A.20-M DESIGN

Traceability requirement:R-40.A.32-M	**Responsible:** AS	**Execution date:** 15.05.2012
Document number:	**Test type:** Visual test	**Test number:**1
Requirement description: The casing should match existing design of the TC2, within the limitations set by Tronrud Engineering.		
TEST		
Expected results: Design is approved.		
Actual results: The design is not approved.		
INFORMATION		
Number of errors:3		
Error description: The plywood chassis, which is a plan B, is not matching the design of the TC2 (1), and is larger than the limitation s set (2). It also lacks casing (3).		
Improvements: Design a new chassis with casing. This is however not possible, given the time left in the project.		
Approved: No.		

T-40.A.21-M MAINTANANCE		
Traceability requirement: R-40.A.33-M	**Responsible:** AS	**Execution date:** 15.05.2012
Document number:	**Test type:** Visual test	**Test number:** 1
Requirement description: The casing shall be equipped with doors so that accessing the spools and threads are easy.		
TEST		
Expected results: Design is approved.		
Actual results: The casing to cover the plywood chassis is not in existence.		
INFORMATION		
Number of errors: 1		
Error description: The doors for the spools are not made, because the casing is not made either.		
Improvements: Design a casing. This is however not possible, given the time left in the project.		
Approved: No.		

T-40.A.22-M DURABILITY		
Traceability requirement:R-40.A.34-M	**Responsible:** AS	**Execution date:** 10.05.2012
Document number: D-03.A.31-M	**Test type:** FEM analysis	**Test number:**1
Requirement description: The attachments of the casing should be robust enough to carry the modules weight and vibrations in operation.		
TEST		
Expected results: The chassis will handle the stresses, and the factor of safety will be ok. This actually is our “plan B casing”, which is made out of plywood.		
Actual results: At a force of 200N perpendicular to the back plate, the factor of safety is still approved at 1.7. The maximum stress is 32.2 MPa.		
INFORMATION		
Number of errors:0		
Error description: N/A		
Improvements: Could make more advanced FEM analysis by incorporating every module to the chassis, but this test shows that the plywood chassis can handle a lot more forces and stresses than the modules are going to expose to it.		
Approved: Yes		

T-40.A.23-M FIXING POINTS		
Traceability requirement:R-40.A.37-M	**Responsible:** AS	**Execution date:** 15.05.2012
Document number:	**Test type:** measuring test	**Test number:**1
Requirement description: The fixing points for the casing and the module shall use the four 6mm existing bolt holes for the front plate of the TC2.		
TEST		
Expected results: The fixing points for the casing and the module are using four 6mm existing bolt holes for the front plate of the TC2.		
Actual results: The chassis cannot be bolted to the TC2, and do not use the four 6mm bolts.		
INFORMATION		
Number of errors:2		
Error description: The plywood chassis cannot be bolted to the TC2, because it is too large. The four 6mm bolt holes on the TC2 can therefore not be used.		
Improvements: Design a new casing, which can be bolted to the TC2. This is however not possible, given the time left in the project.		
Approved: No.		

T-40.A.71-M CASING THICKNESS		
Traceability requirement:R-40.A.61-M	**Responsible:** AS	**Execution date:** 15.05.2012
Document number:	**Test type:** prototype test	**Test number:**1
Requirement description: The casing shall be minimum 1 mm thick		
TEST		
Expected results: The panels holds the correct thickness		
Actual results: The casing is not in existence.		
INFORMATION		
Number of errors:1		
Error description: Because the casing does not exist, we cannot measure the thickness.		
Improvements: Design a casing. This is however not possible, given the time left in the project.		
Approved: No.		

T-40.A.72-M CHASSIS THICKNESS		
Traceability requirement:R-40.A.62-M	**Responsible:** AS	**Execution date:** 15.05.2012
Document number:	**Test type:** prototype test	**Test number:**1
Requirement description: The chassis for the module shall be minimum 2.5 mm thick		
TEST		
Expected results: The panels holds the correct thickness		
Actual results: The plywood chassis measures 15mm thick.		
INFORMATION		
Number of errors:0		
Error description: N/A		
Improvements: This is a plywood chassis, so it had to be 15mm thick to have strength enough matched with sheet metal. A redesign would make the chassis better.		
Approved: Yes.		

T-40.A.73-M SYSTEM MOUNTING		
Traceability requirement: R-40.A.63-M	**Responsible:** AS	**Execution date:** 25.05.2012
Document number: D-00.A.33-EM	**Test type:** prototype test	**Test number:** 1
Requirement description: The system shall be mounted to the chassis plate		
TEST		
Expected results: The modules fits without interacting with each other		
Actual results: All modules fit the plywood chassis with small modifications.		
INFORMATION		
Number of errors: 0		
Error description: N/A		
Improvements: Make a chassis out of sheet metal and fit the modules on it		
Approved: Yes.		

T-10.B.27-M REPLACE TIME

Traceability requirement: R-10.B.03-M	**Responsible:** VK	**Execution date:** 28.05.2012
	Test type: Prototype test	**Test number:**1
Requirement description: Replacing the gripper shouldn't take more than 20 minutes.		
TEST		
Expected results: Replacing the gripper will not take more than 20 minutes.		
Actual results: Replacing of the gripper is performed and it does not take more than 20 minutes. The actual time result is less than 2 minutes.		
INFORMATION		
Number of errors: 0		
Error description: N/A		
Improvements: No improvements.		
Approved: Yes.		

T-23.B.88-EM SPOOL VARIATION		
Traceability requirement: R-23.B.77-EM	**Responsible:** AS	**Execution date:** 21.05.2012
Document number:	**Test type:** prototype test	**Test number:** 1
Requirement description: The system shall be able to hold cylindrical spools		
TEST		
Expected results: The cylindrical spools fit		
Actual results: The cylindrical spools fit, and can be used as long as they have an inside diameter of more than 6mm and are smaller than 15cm high and 10cm wide.		
INFORMATION		
Number of errors: 0		
Error description: N/A		
Improvements: test with more cylindrical spools		
Approved: Yes.		

BUDGET FOR THE "AUTOMATIC SHUTTLE CONTROL SYSTEM"

D-08.A.13-A

Release 3.0

RELEASE NOTES

Date	Version	Description	Author
09.01.2012	0.1	First draft	Eirik Nordstrand
09.01.2012	1.0	Finishing budget document	Eirik Nordstrand
06.03.2012	2.0	Finalized document	Eirik Nordstrand
29.05.2012	3.0	Updated budget Finalized document.	Eirik Nordstrand

ABOUT THIS DOCUMENT

This document contains the estimated and accurate costs for the project. Please note that it does not include accurate costs for the printed documents for the 3. presentation and the costs for biscuits and soda on the third presentation.

Cost overview for ASCS

Article	Amount	Unit price (kr)		Total costs (kr)	
		Estimated	Accurate	Estimated	Accurate
Documentation 1. presentation					
Blue ring binder, internal sensor	1	30,00	31,00	30,00	31,00
Separator sheets	1	20,00	19,00	20,00	19,00
CD	1	10,00	10,00	10,00	10,00
Copy costs, first presentation - B/W	570	0,80	0,80	456,00	456,00
Costs for 1. presentation					
Biscuits	2	20	29,00	40,00	29,00
Soda	1	25	0,00	25,00	0,00
Coffee	1	50	120,00	50,00	120,00
Coffee cups	1	30	29,00	30,00	29,00
Documentation 2. presentation					
Blue ringbinder, internal sensor+advisor	2	31,00	31,00	62,00	62,00
Separator sheets, internal sensor+advisor	2	20,00	19,00	40,00	38,00
Copy costs, first presentation - B/W	412	0,80	1,00	329,60	412,00
Costs for 2. presentation					
Biscuits	1	20	12,90	20	12,90
Soda	1	50	48,00	50	48,00
Bag	1		0,80		0,80
Coffee	1	120	135,00	120,00	135,00
Documentation 3. presentation					
Blue ringbinder, internal sensor	1	20,00		20,00	0,00
Copy costs, first presentation - B/W	678	0,80		542,40	0,00
Costs for 3. presentation					
Biscuits	3	20		60	0,00
Soda	3	25		75	0,00
Electrical parts					
Sensors					
Eltex - Weft Sensor G3w (in NOK) + MOMS	1	2084,00	1344,75	2084,00	1344,75
Microcontroller					
STK600 /w Atmega128RFA1		0,00	0,00	0,00	0,00
Motor					
Motor for gripper arm (Exmec)					0,00
Motor for thread selection (Faulhaber)					0,00
BLDC Speed controller					0,00
Electrical components					
DAC	1		80,25		80,25
op-amp	1		19,19		19,19
5V voltage ref.	1		57,85		57,85
12V voltage reg.	1		6,71		6,71
Expedition/fee	1		116,00		116,00

Mechanical parts				
Casing (Plywood, screws, nuts, cable clips)	1	462,97	200,00	462,97
Gripearm (tape, tools, scissor, Sandpaper, measuring tape)	1	312,20	200,00	312,20
Gripper			150,00	0,00
Gripper arm feeding (Sandpaper, measuring tape)			0,00	0,00
Div. components from SDP/SI	1	1429,13		1429,13
Thread holding/feeding (Threaded rod and hooks)	1	82,00		82,00
Other				
Lock tight	1	32,90		32,90
El-tape	1	11,90		11,90
Scissor (for the lego prototype)	1	12,00		12,00
Nullmodemkabel	1	79,00		79,00
Super glue	1	10,00		10,00
Div. equipment and power switch	1	134,60		134,60
File (tool)	1	44,90		44,90
Documented transport				
Horten-Moss farry	1	198,00		198,00
Oslofjordtunnelen	1	60,00		60,00
Posten, return of motor controller	1	170,00		170,00
Total sum			4614,00	6067,05
Unexpected costs				
Add 30 %			1384,2	0,00
Finished complete costs			kr 5 998,20	6067,05
Diff.			kr -68,85	

FINAL ANALYSIS OF "AUTOMATIC SHUTTLE CONTROL SYSTEM"

D-00.A.37-A

Release 1.0

TRONRUD ENGINEERING AS

RELEASE NOTES

Date	Version	Description	Author
27.05.2012	0.1	- First draft: Draft for about this document Draft for introduction	Mats Strand Sætervik
28.05.2012	0.2	Added: Draft, Cooperation with employer Draft, Cooperation with internal adviser	Mats Strand Sætervik
28.05.2012	0.3	Added individual analysis for AS Added individual analysis for EN	Andreas Stustad Eirik Nordstrand
29.05.2012	0.3.1	Added individual analysis for AV Group cooperation Internal adviser cooperation Conclusion	Andreas Vander Inge Ytre-Eide
29.05.2012	0.3.2	Added individual analysis	Mats Strand sætervik
29.05.2012	0.3.3	Added individual analysis	Vazgen Karlsen
29.05.2012	1.0	Finalized document	Eirik Nordstrand

ABOUT THIS DOCUMENT

This document contains our summary/final analysis for this project. It describes the groups and its member´s conclusions and analysis of this project.

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INTRODUCTION

This document describes the group's summary of the project. The document is divided into two parts, one contains the group common analysis. The second part is each members own analysis.

The first part contains the group analysis of group cooperation, cooperation with advisers and a summary of the project workflow and results. As a part of writing this document the group and the group members will try to answer what we are satisfied with and what could have been done different. The group will provide feedback to external and internal advisers, explaining our experience.

The second part contain each members interpretation of their own effort, responsibilities and a analysis of what was done well and what could have been done better. The group members will describe what they have been working on, describe their own knowledge to their own responsibility, their general knowledge about the project and how they have influenced the project, both good and bad.

Finally a conclusion is presented.

PROJECT SUMMARY

The groups were given this assignment after sending an application to Tronrud Engineering.

The task was initially described in an e-mail as follows:

Designing and construct an automatic pick where:

- A mechanic shuttle is propelled automatically through the warp in a loom
- The shuttle can either leave a thread when crossing or pick up a thread and return
- The system has to contain 5-6 spools with different colors. The system has to automatically attach the chosen thread to the shuttle, each pick.
- When the shuttle has deployed the thread through the warp, the thread has to be secured so that it doesn't interferers with the next pick.
- The weaver performs the beat manually, a comb pressed the thread into the weaved material.
- The automatic cycle repeats itself

Special challenges:

- Tight space, compact solution is required
- Safety considerations
- Module based system. The product has to be easily retrofitted on the loom.

The group initial impression of this project was that this was an exciting task that could cover both fields of expertise.

The first meeting with Tronrud Engineering where held at their location the 21th of September.

The group had high ambitions, right from the start of the project. And throughout the inception and elaboration phase the group has aimed for developing a fully functional product that would meet almost every requirement.

The requirements have been set so that the finished product could be attached to the TC2. After the first meeting the group decided to work with a few goals in mind:

- The product would be easily fitted to the TC2, as a plug and play module.

- The group wanted the product to produce at least as many pick per minute as a weaver, which can be as high as 30 pick per minute.
- The product would be small enough to fit within Tronrud Engineering wishes.
- The system can handle 8 different spools, and all of these will be fitted on our product.

The developing of design ideas has been a common responsibility. The group struggled to come up with functional ideas for the whole group. The problem wasn’t only to come up with them, but also how the parts could be assembled and made. The original design included small and specially made parts. Finding suppliers and redesigning to make the product easier to produce, has taken a lot of time.

The group worked with these with these goals until the first elaboration phase. The group realized that most of our requirements and ambitions where to high. Some design ideas were too expensive and the group had to develop a prototype that would reduce building costs and this wouldn’t meet the initially goals and requirements. When this becomes clear, many of the group members felt disappointed.

When some of the design changed, some of the demands changed. But the group kept many of the demands even though the prototype would fail to meet these requirements. The group feels that the current prototype can be a proof of concept, but in order to fit this to the TC2 they have to be smaller and more parts are needed. The design for the backup prototype uses the same concept ideas, there are just fewer or larger parts. In order to summaries this, the group has develop an own document. This presents which design we think is good and suggestions to improve others.

The group has constructed a working prototype. Some of the design ideas had flaws, and this have been discovered and modified. The group is satisfied with completing a working prototype. But to a lot of time has been spent on making this work, this has led to less testing and documentation. If the group had managed to get the prototype assembled and working earlier more tests would have been completed and more requirements would have been met.

GROUP COOPERATION

Most of the project the group has been gathered in one room, working with their assigned tasks. In the elaboration iterations, we spent most of our time designing and researching different modules. We divided the group into 3 and gave them a module each to work on. Each team had one from electro and one from machine. These lines were very defined, but if one team was stuck or just wanted some inputs, they got it from the rest of the group.

Seeing that we have worked ~4000 work hours together and had no conflicts, must be an great achievement. The group has discussed during the whole project, some discussions turned out to be long and exhausting, but nevertheless made this project better. But there is still some disagreements around the documentation, the solutions and how to work the most efficiently, but we`ve always let the majority rule after an discussion.

One of the major reasons we didn't have any conflicts, is that every group member does their assigned task and works continuously. If the member was free of work, which rarely happened, they asked if anyone else needed help.

COOPERATION WITH OUR EMPLOYER

Throughout the project we have attended three meetings at Tronrud Engineering. The meetings have been held to discuss the task, project process and suggested solutions.

After the first presentation the group was aware that we could improve our communication with external advisers. We could improve this communication by asking often and sooner, this way misunderstandings could be more easily avoided.

During the second elaboration and the rest of the project the group got better at communicating with internal advisers. Even though we had to ask questions almost every day though a period of the project, the external advisers answered them quickly and provided us with informative and helpful feedback.

The group realizes that we have had problems limiting the assignment and understanding what the employer wants from our product. Our own ambitions were probably too high, and this may have led to too high demands and expatiations.

This project has been a most interesting and challenging assignment. The assignment covers several areas and is very suitable for this kind of group composition. A given budget for our assignment might have shortened the decision time for some of the designs and solutions.

COOPERATION WITH INTERNAL ADVISER

In the start phase of this project, we had some misunderstandings with our internal adviser, Hallstein. This was mostly in the layout and set-up of documentation, meeting summaries and the follow-up documents. There were many times that we felt that Hallstein changed his mind from week to week, but after this was brought up, we decided that we should ask more questions about unclear feedback and he should become better at clearing it for us. Misunderstandings rarely happened after this. He guided us with the use of very constructive feedback, but we feel he could have pushed us more, both in the generation of documentation, routines and work progress. We had a 3 incidents were we forgot to send his meeting invitation, but he was kind enough to come nevertheless.

All in all, he`s been a great guide throughout this project. He has been fairly easy to reach when we had questions and were flexible about delivery of documentation for feedback.

INDIVIDUAL ANALYSIS

Here each of the project´s members have written their own analysis of this project, what they have done and how the project went according to them.

INGE YTRE-EIDE

When this assignment began last semester (September 2011), I really did not know what to expect, but as the group formed and we got a project from Tronrud Engineering. Our task was mainly to automate the weaver’s task of guiding the shuttle through the warps. We divided areas of responsibility. Mine were Design and back-up. The responsibility for design were out phased as the project moved forward as the most of the group contributed with ideas to design and solutions. Especially after we discovered that our original design had to be discarded due the complexity and cost. As we started the project, I was very ambitious, hoping that we could design and construct a fully functional prototype. But as the project moved on, and I saw that the solutions that we had thought up around thread selection, the area of design responsibility of Andreas V. and me, were too complicated for the given timeframe (the electrical part of the controlling of the arms in thread selection) and the hardware (motors, microcontrollers and other mechanical parts) became too expensive. This was a rather big disappointment for me, both regarding my insufficient knowledge regarding the development of BLDC drivers and the extreme cost for the parts. The result of this was that we had to discard and adapt most of the design, and hence not meet the requirements that were set. In the end, we still were able to design and construct a functional prototype and I`m very pleased with this.

This project has given me a lot of useful experiences, mostly around how to work in team with parallel developments of parts/modules and how to design cost efficient, both in regards to part costs and work hours needed for assembly. The part of working as a group has been very rewarding seen from en educational point of view, since everyone has to adapt their work methods to some extent. I was also rather surprised over how efficient we were during our parallel working with the different modules. This required planning, which wasn't at its best at all times, but everyone had something to do and knew when they had to finish it.

To sum it up, we were handed a rather big project, started of way to ambitious and failed at some points but hopefully we recovered from this to some extent. I feel that we did a great job as a group and I hope I share this opinion with the rest of the group.

ANDREAS STUSTAD

When this project began in September 2011, I was looking forward beginning the project. In the beginning before the first presentation we were using a lot time for studying our assignment and write documents and setting up the requirements and tests specification. We did possibly not work systematical before first presentation, because we got a little busy with editing documentation. After the first presentation, we started developing our ideas and solutions. I got the responsibility on the thread holding system, the thread feeding system and the casing/frame. I was also assigned mechanical leader and responsible for the requirement specification. Me and Eirik worked mostly on the thread holding system, and tested a lot of ideas on LEGO. In my opinion, we used too much time going back and forth from idea to idea. We were aware of this, and this is why we documented a lot. The problem was that we wanted to make a system that worked on every spool and thread as well as being cheap to make. I thought it was cheap enough, but we had to redesign the thread holding system, and use more sheet metal design. I redesigned again, but had still some problems that needed solving, which took a lot of time. All this time trying to figure out the best solution for the thread holding system, set the development of the casing and frame back, as well as the thread feeding system. I did some design, but the other modules did not fit the chassis. Because of this, I later made a plywood chassis instead. Against the end of the project, I voluntary worked on documentation and planning, which needed a lot of work.

I think I have worked well with the project and I have experienced much about working in a project on a strict budget and limited time. I know that I have worked less than other group members up to the second presentation, but I feel I have worked more after the second presentation. The other subjects and exam preparations took a bit of my time from this project, especially in April. I have experienced working in a group for a longer period of time than before and cooperating doing activities or assignments. I think I could have been much better to set me into the design of other group member as a mechanical leader, but I feel I have worked well.

VAZGEN KARLSEN

I was very excited when the project started back in September 2011. I was excited to use the knowledge and experience that I had achieved through my studies at Buskerud University College. The first impression that I got from the assignment we been given from Tronrud Engineering, was the size of the assignment considering number of required components and innovative challenging solutions. It has also been kind of a motivation factor for me through the whole project.

We started the project by making documents that was necessary further in project and researching similar solution forward to the first presentation. After first presentation we started to look deeper into our ideas and solutions.

I have mostly been working with Mats around solution for the Feeding mechanism for gripper arm and documentation around it. It was time consuming process considering discarded solutions and designs. Responsibility I had through the project was test specification and planning around it. Planning around it was a difficult process considering completing of CAD drawings and finally delayed ordering of parts. Test plan could be planned better, but priority was given to produce the prototype. I have also parallel been working with constructing of the holder and cutter with Andreas Vander that we finally completed and implemented to the prototype.

I feel that I could participate much more in planning phase, but I still mean that I have done a god job. Our prototype does not meet all requirements, but we can still present proof of our concept. I think the prototype and documentation around it is useful research for Tronrud Engineering, even if the prototype does not fits to the TC-2.

ANDREAS VANDER

When starting the project we were all given different responsibilities, I was given the responsibility of CAD models and risks. After the first presentation we started on the technical solution and design. We were not able to handle all risks that occurred under second elaboration phase. We were falling behind schedule, the module holder and cutter was not even started. The 2nd presentation was coming up and documentation had to be finalized. Parallel to writing all documentation we had to finish our design and deliver 2D drawings for production. Since the delivery time for the produced parts were 4-6 weeks we had to set a deadline for delivery of 2D drawings. Sickness also occurred during second elaboration phase. To solve the situation we agreed to prioritize tasks so we would be able to produce a prototype. After the 2nd presentation we were able to finalize 2D drawings and sent them for production before the deadline. As responsible for risks I saw that I should have had more concrete prevention and a larger time buffer.

I worked with Inge on the design and solution for the thread selection. The first design idea we did come up with and presented were too expensive. During waiting time on pricing and delivery time for this design I started on a cheaper backup solution which I also presented for Tronrud Engineering per mail. I presented the two solutions with pricing and the problem with requirements that would fail on the backup solution. The decision fell on the backup design as it would test our solution for a much lower price. Under the design and solutions for the module we were behind schedule and there were a chance we would not be able to produce a prototype. I also worked with Vazgen on designing a functional holder and cutter for the prototype later on in the project so we would get a functional prototype. All in all I am very satisfied that we managed to produce a prototype which is functional.

Working in a team over a longer time with a project on this size has been a new experience for me which has given me a lot. At the start of the project (September 2011) I was excited about the project when we got the assignment from Tronrud Engineering. During this project I have been able to put what I have learned during my three years at BUC into practice.

EIRIK NORDSTRAND

This is the first project of this size I have participated in. Project ASCS has given me a lot of challenges and experiences. It has given me the opportunity to use what I have learned previously at the school, in practice.

Besides being the responsible for the economics and documentation for the group, I've also worked on the electrical solution regarding the Thread/spool holding- and feeding system. This have primarily been interacting the weft sensor with the Atmel microcontroller. I have also cooperated with Andreas Stustad with the basic design of the module.

The project has been a bit time consuming, and I have spent a lot of evenings and weekends at the school working with the project. A lot of this time has been used to work around- and troubleshoot the problem with current leakage on the Port E. I'm satisfied that I found the solution of the problem. Much time has also been used to familiarize me with the microcontroller. We have not previously used Atmel microcontroller, so I needed some time to read the datasheet and understand the different registers that we had to modify.
Another very time consuming activity have been spelling and grammar of all the documents, and finalizing documents.

One thing I want to emphasize is that I got an early start with the electrical components on the module. As early as in the middle of January, I contacted, among other, Eltex of Sweden after a research of different weft sensor providers in the world. They gave us excellent support and helped us to find the sensor that would be best suited for our product. We ordered this sensor 15th of February. We also got the microcontroller from our employer 1st of February. This gave me the opportunity to learn the basics for the microcontroller, and also interact the weft sensor with the microcontroller, while the other group members were busy with their research. In that way, I could help them to get fast into the programming when they got their components.

In summary I will say that even though I have spent a lot of time in this project, I will not say that I have wasted any time. We have had an assignment with a lot of challenges, and with all the new practical experience we have got, I think it would be necessary to use all this time to get a finished prototype and documentation.

MATS STRAND SÆTERVIK

In this project my main responsibilities have been group leader, vision document, home page and project plan. With the responsibility of group leader and project plan I have worked work with hours list, gantt diagrams, project and iteration plans and communication with advisers.

A have also worked on the feeding mechanism for the gripper arm together with Vazgen. My main responsibility on the feeding mechanism has been to research motors and finding a suitable motor for the module. This has been done by investigating possible solutions and then we have used a motor and controller provided to us by Tronrud Engineering. In order to control the motor, two methods have been worked on. One was to develop a more complicated algorithm that the one we use now.

I have been working with both the NI-USB 6008 and ATmega128RFA1. The NI-USB 6008 was used on the Lego prototype and as a DAC for testing, when a DAC wasn't available. In order to develop a software for the ATmega128RFA1 I had to familiar myself with the registers for the counter and the external interrupts in addition to general configurations of I/O pins. When the prototype arrived, I work on integrating all the software, using functions created by other group members, into one main program and testing the prototype.

I have tried to contribute on other modules if deadlines were fast approaching. I have for example used CAD tools (SolidWorks) and modified mechanical components. I have tried to delegate as much work as I could, but much of the time has been used on making sure all modules were produced.

The home page could have been better and could have been updated more often.

Since I have been included in many of the modules and contributed on several fields, I have been able to understand much of the problems and solutions for the whole project. Understanding and working with other students in a different field of expertise has been a valuable learning experience. I have also been able to apply what I have learned the last three years in a practical application, when developing software and hardware for this product.

CONCLUSION

We started this project with high ambitious and we keep this for too long. This resulted in to high requirements and therefore took us to long time to acknowledge that we had to build a cheaper system and less sophisticated. Most of the group members were disappointed when we had to discard our original design, but came over it to some extent.

This project has given us much needed experience in how to design for commercial use, cost- and design wise. Tronrud Engineering also showed us how to use thin bent metal sheets for construction of modules to minimize assembly cost.