PROJECT REPORT

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TITLE:

SIMPLE WINCH FOR SEAFARM

SUMMARY:

This report is a final report in the subject "Innføring i Mekatronikk", IP304814 at NTNU in Aalesund. The project issued in this report is to construct a simple winch to connect two earlier project at the university. This winch aims to connect a platform and a ROV to make a complete product, to be used to inspect seafarms. The winch is mostly made from 3D-printed parts, and is therefore exploring the possibilities this utility gives us as engineers. The winch has been mounted to the platform, also provided with a locking tool for the ROV in standby-mode. The platform has been modified with increased initial buoyancy to compensate for the added weight.

This project is handed in for evaluation and accreditation at NTNU in Aalesund.

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SUMMARY

This report is a final report in the subject “Innføring i Mekatronikk”, IP304814 at NTNU in Aalesund. The project issued in this report is to construct a simple winch to connect two earlier project at the university. This winch aims to connect a platform and a ROV to make a complete product, to be used to inspect seafarms. The winch is mostly made from 3D-printed parts, and is therefore exploring the possibilities this utility gives us as engineers. The winch has been mounted to the platform, also provided with a locking tool for the ROV in standby-mode. The platform has been modified with increased initial buoyancy to compensate for the added weight.

TERMINOLOGY

ROV – Underwater robot

DP – Dynamic Positioning, using thrusters to stay in place based on GPS signals.

JAVA – Java is an object-oriented programming language

IDE - Integrated Development Environment)

Arduino - Arduino is a platform for prototyping of electronics based on open source software and hardware.

Arduino IDE - This is a multi-platform program written in Java, based on the development environment of the Processing and Wiring platform.

Netbeans - This is a software development platform written in Java.

NETBEANS IDE - The NetBeans IDE is primarily intended for development in Java, but also supports other languages, in particular PHP, C/C++ and HTML5

TCP/IP - Transmission Control Protocol/Internet Protocol) its a group of communication protocols that are used to connect computers to networks.

JDK - Java Development Kit

Odroid - This is a series of single-board computers and tablet computers
PWM –Pulse breadth modulation

IP - Internet protocol address

USB - Universal Serial Bus

DC - Direct Current

CoG – Center of gravity

OD – Outer Diameter

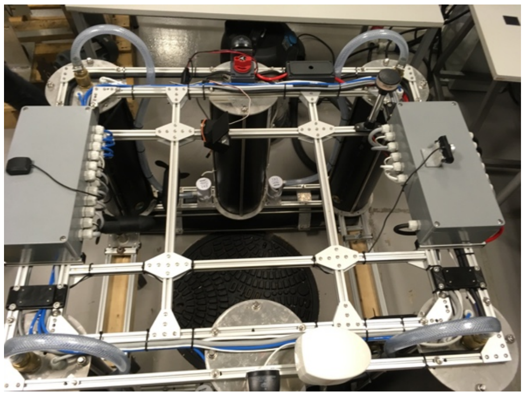
1 INTRODUCTION

A simple winch is to be designed to connect a ROV to a SeaFarm-platform, both projects from earlier terms of the subject or bachelor thesis. By doing this, we are making a complete system for inspecting sea farms at a depth of 7m.

The task for this project is connecting the ROV to the platform via a simple winch. This makes for a challenge regarding the winch design, buoyancy of the platform, powering and signals to/from the ROV and locking the ROV in a standby-position when the system isn't in use. Following, the Scope of Wrok is given:

Project Introduction:

The SeaFarm is an on-going project at NTNU in Aalesund, Norway. The project aims to build an efficient, cheap and reliable SeaFarm for inspection of underwater environment, especially within the fish breeding industry. Today, the SeaFarm consists of two main parts, to be attached together to make the farm complete.



The two parts, a platform and a ROV is to be connected to form a complete working system to inspect the fish breeding nets.

The platform measures approximately 1 m x 0.6 m x 1 m, and is made of affordable and common materials, which makes it both cheap and relatively small. The platform has a type of ballast-water system, making it able to adjust to heel and trim. It is also equipped with thrusters, making it able to move in the water. The platform weights 115 kgs.

The other part, a ROV is made with three thrusters, giving it the ability to move in all directions in water. It is fitted with a camera for inspecting, and weights approximately 13 kgs.

Project Task:

This semesters project in the subject "Innføring I Mekatronikk" is to attach the ROV to the platform with a simple winch.

The project task includes:

- Making the winch and power it with the batteries on the platform
- Assure the ROV is not disturbed by heave on the platform
- Locking the ROV in position when the SeaFarm isn't in use.
- Holding the platform at a given depth in the water.
- The ROV is to be lowered to a depth of 10 m.

This task also makes for a few adjustments on the existing parts to be done:

- Collecting the cables of the ROV (CAT 5 and power supply) into one, with an additional steel wire for the winch.
- Improve the initial buoyancy of the platform, as is would sink with the ROV in place with the current design.

Attached to this report is the (complete) scope of work [Appendix 1], giving us the basis for the project.

2 BACKGROUND AND THEORETICAL BASIS

The ROV was made in 2016, and is to be used for inspecting sea farms, collecting biological data etc. It uses cameras and external lights for inspection and has three thrusters attached for manoeuvring. It must be powered through the platform's batteries.

The platform was a bachelor thesis with POD/Automation-students in 2017, complete with stability-control and thrusters for DP. It is powered by batteries in the bottom buoyancy pipes.

Theoretical basis in this project includes:

2.1 GEAR AND TORQUE CALCULATIONS

The ratio and the number of teeth of the planetary gear is calculated with the following equation:

$$R = (2 \cdot P) + S$$

$$Ratio = \frac{R}{S}$$

R = Number of teeth ring gear

S = Number of teeth sun gear

P = Number of teeth planetary gear

The calculation of the torque is based on the assumption of a velocity and a drum diameter. The rotation speed is given as:

$$\omega = \frac{v}{r}$$

ω = Rotation speed

v = Linear velocity

r = Radius drum

Critical torque will occur when the ROV is above sea-level and is given as:

$$T = \sum(F \cdot r)$$

T = Torque

F = Forces

r = Radius drum

2.2 BUOYANCY

The buoyant force of a body is calculated as

$$B = \rho V g$$

Adding the weight of the body of

$$W = -mg$$

We get a sum of forces indicating if the body will float or sink. A positive sum of forces indicated a floating object, while a negative sum means the body will sink. We get

$$F = -mg + \rho V g$$

2.3 Calculations Locking mechanism

Hooke's law regarding extending or compressing a spring

$$F = kx$$

F = Force needed to extend or compress a certain spring

k = Constant factor

x = Distance of extension or compression

Critical torque will occur when the springs are extended at chosen max length:

T = Torque

F = Force

r = radius pulley

2.3 Slip Ring Calculation

The slip ring is dimensioned according to the ROV specifications as stated in the report from the mechatronics task from the autumn of 2016. The slip ring is dimensioned with respect to the current and the speed of the ethernet cable (CAT 5).

2.4 Materials

We decided early on to try constructing the winch using 3D-printers and materials available on the university.

2.4.1 3D-printing

When issued with the task, we decided to use 3D-printing for manufacturing parts for the winch and the project systems. This was mainly because of the rather weak forces acting on the system. 3D-printing is part of the Industry 4.0 [1] manufacturing trend, using automotive technology and computing systems for manufacturing of parts. We have 3D-printers from Ultimaker at the university, providing a possibility to construct advanced geometry in hard plastic materials, mostly PLA. The PLA has a density of 1240 kg/m^3, making it lighter than steel and aluminium. PLA has the following specifications [2]:

Figure 2-1 Ultimaker 3D-printer

Mechanical properties (*)	Injection molding		3D printing	
	Typical value	Test method	Typical value	Test method
Tensile modulus	-	-	2346.5 MPa	ISO 527 (1 mm/min)
Tensile stress at yield	-	-	49.5 MPa	ISO 527 (50 mm/min)
Tensile stress at break	-	-	45.6 MPa	ISO 527 (50 mm/min)
Elongation at yield	-	-	3.3 %	ISO 527 (50 mm/min)
Elongation at break	-	-	5.2 %	ISO 527 (50 mm/min)
Flexural strength	-	-	103.0 MPa	ISO 178
Flexural modulus	-	-	3150.0 MPa	ISO 178
Izod impact strength, notched (at 23°C)	-	-	5.1 kJ/m²	ISO 180
Charpy impact strength (at 23°C)	-	-	-	-
Hardness	-	-	83 (Shore D)	Durometer

Figure 2-2 PLA data

2.4.2 Other materials

Where 3D-printing and PLA could not be used, we went for aluminium, and in some cases stainless steel. This is addressed in the parts list.

2.5 *STEPPER MOTOR CALCULATION*

To figure out how much a stepper motor has to rotate to e.g. let out 1m of cable, one has to use the drums circumference.

$$1m\ cable\ =\ C\ *\ n_c$$

Where C is the circumference and n_c is the number of turns needed to let out/in 1m cable.

Using the gear ratio G_r, one can determine the number of steps needed to let out 1m of cable.

$$N_{motor} = n_c * G_r * S$$

Where S is the number of steps the stepper motor has to do to complete one round.

3 PARTS FOR AUTOMATION

3.1.1 Arduino uno

Arduino uno is a microcontroller that you can easily program to perform different actions. The microcontroller sends signals that are between 0 - 5 V and Sets the speed (baud rate) for the serial communication. Supported baud rates are 300, 600, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 31250, 38400, 57600, and 115200.

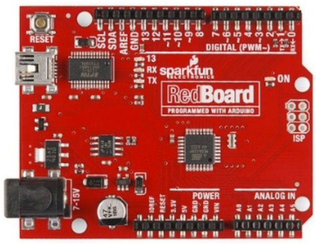


Figure 3-1 Arduino Uno

3.1.2 Dc motor driver

The DC stepper motor driver is controlled by 5V signals, as in this situation we send signals from the arduino UNO board. This driver converts the signals so that it can drive stepper motors that require up to 40V and 4A, with the vanity to adjust the amount of stepping, rotation direction and has a hold function.

Figure 3-2 DC Motor Driver

3.1.3 Serial communication cable

A serial cable is a cable used to transfer information between two devices using a serial communication protocol. The form of connectors depends on the particular serial port used. In this case we use a USB 2.0 type A to Mini-B 5-pin cable.

Figure 3-3 Serial Communication Cable

3.1.4 Signal and power cable

Signal cable is a CAT 5 Ethernet cable from bluerobotics like
is designed to carry cargo. The stated workforce is 35kg and
breaking strength of 155kg. The power cable used in this project are two single conductors 4x2mm^2 cable. This was chosen based on the weight and thickness of the cable.

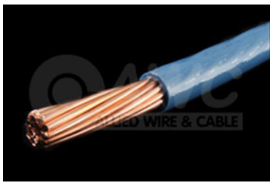


Figure 3-4 Power cable

3.1.5 Stepper motors

A stepper motor is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps. We used a small Nema 23 stepper motor and a PD86-3-11180 Stepper motor from Trinamic.

Figure 3-5 PD86 Stepper Motor

Figure 3-6 NEMA 23 Stepper Motor

3.1.6 Router

A router is a networking device that forwards data packets between computer networks. We used a Wireless Router TL-WR841N.

Figure 3-7 Router

3.1.7 Motor shield

Motor Shield is a driver module for motors that allows you to use Arduino to control the working speed and direction of the motor. We used a shield from Adafruit that works for Motor/Stepper/Servo for Arduino v2

Figure 3-8 Motor Shield

3.1.8 End switches

Limit switch is a switch operated by the motion of a machine part or presence of an object.

Figure 3-9 End Switch

3.1.9 Wifi antenna

Wi-Fi is used for low-cost, unregulated point-to-point computer network connections. We use a WiFi Module 3 for ODROID

Figure 3-10 Wifi Antenna

3.1.10 Converter

DC / DC converter 15...24 VDC from Vanson Electronics.

Figure 3-11 Converter

3.1.11 Odroid 4XU

Odroid is a series of single-board computers and tablet computers created by Hardkernel Co. A hardware company located in South Korea.

Figure 3-12 Odroid 4XU

4 METHODS

Giving the challenges we face in this project, we've split the scope of work into the following pieces in addition to building the actual winch.

- Designing and building a lock in standby-position.
- Increasing the buoyancy.
- Creating a solution for leading the wire onto the drum.
- Creating a program in Arduino that will be the software of the winch.
- Creating serial communication between the winch controller and the platform's controller "Odroid"
- Create a Client Server solution, which allows us to control the winch through WIFI.
- Replace current signal and power cables to ROV. To a cable that is more suitable for the winch
- Prepare New Ordroid on the Seafarm since the old has been removed.

INITIAL SOLUTIONS FOR THE WINCH PARTS

4.1 DESIGNING AND BUILDING THE WINCH

The winch with the drum is to be designed used a 3D-software. The winch consists of the following main parts: motor, transmission and drum. For modelling the parts, we've used AutoDesk Fusion 360, allowing us to collaborate together.

Also using 3D-software, we are to design a solution for the locking of the ROV in standby-mode. It should be locked both horizontally and vertically.

The size of the platform makes for a large angle between the pulley and drum, so that we must make a leader for the wire.

4.1.1 Increasing the buoyancy

The buoyancy at the current state is at a critical point, making the platform (at least nearly) sink when attaching the winch and the ROV. There shall be added pipes for increased buoyancy so that the draft is at a satisfactory point when the system is built complete.

INITIAL SOLUTIONS FOR THE AUTOMATION PART

4.1.2 Design a software that controls winch and ROV docking

This software must have full control of the following actions:

- depth of ROV
- winch in lock or in open position
- prepare ROV docking and ROV deployment preparation
- adjust speed on winch
- emergency stop
- a solution for retrieving ROV after power failure.

When building a program with this type of commands, it would be natural to use the switch case method on the Arduino.

4.1.3 Connecting the ROV to the platform with power and internet signals

Another big challenge is leading the power and signals through the drum, to and from the platform and the ROV. This is to be solved using a slip ring, and leading all wires and cables through one heat shrink or similar.

4.1.4 Create a TCP / IP server and client that can be used on an external platform

Create a server that have the ability to connect to with an external PC. Where the server must be able to run on the seafarm where we only have access to 12V. Server and client should communicate through WIFI. As an emergency solution, there are possibilities for Bluetooth communication.

4.1.5 Install a new Odroid on the SeaFarm

Installing the new Linux Ubuntu desktop system, desktop version. Install the latest Netbeans with updated JDK custom Linux. COM ported for Serial Communication between Arduino and Ordoid must be adapted. Port number 1500 also have to be modified, so that it has the ability to read and write. This is necessary for the client server solution to have the opportunities to communicate on this port.

This is time consuming work.

4.1.6 Find a method to make an economical ROV cable solution

Here, the old 4x4mm^2 power cable is replaced with two new single wires on 4mm^2 cables. It is also necessary to add a new steel wire to handle 50 kg to prevent wear on the CAT 5 cable as today, taking care of all the weight. Then all of these cables must be put into a protective cover for preventing fractures

4.1.7 Programming

For the development of source code for the winch and docking station, we have used Aruino's IDE based on JAVA. And we have used Netbeans IDE where we have the opportunity to develop GUI and program code. Netbeans supports several different programming languages, such as Java, PHP, C / C ++, CSS, and more.

4.1.8 Microcontroller Code

The microcontrollers we have used are Arduino. Here we have the ability to develop code in the program that Arduino itself has developed "Arduino IDE". The program contains features like Serial.Write () or Serial.Read () which are functions for sending or reading data sent with serial communication. In our code wants to deal with features like PMW, Analog Serial Read and Write. With PWM the Arduino has the ability to scale down 5V to 256 steps.

4.1.9 Simulation of Arduino program

In order to test run the winch control program we made a "simulator". It was used for simulation of the different action. The simulation was in the first phase only LED lights that lit when different commands were performed, it was later replaced by simple small stepper motors and end switches. This was done because we wanted the program to be optimal on the day the winch was ready for testing.

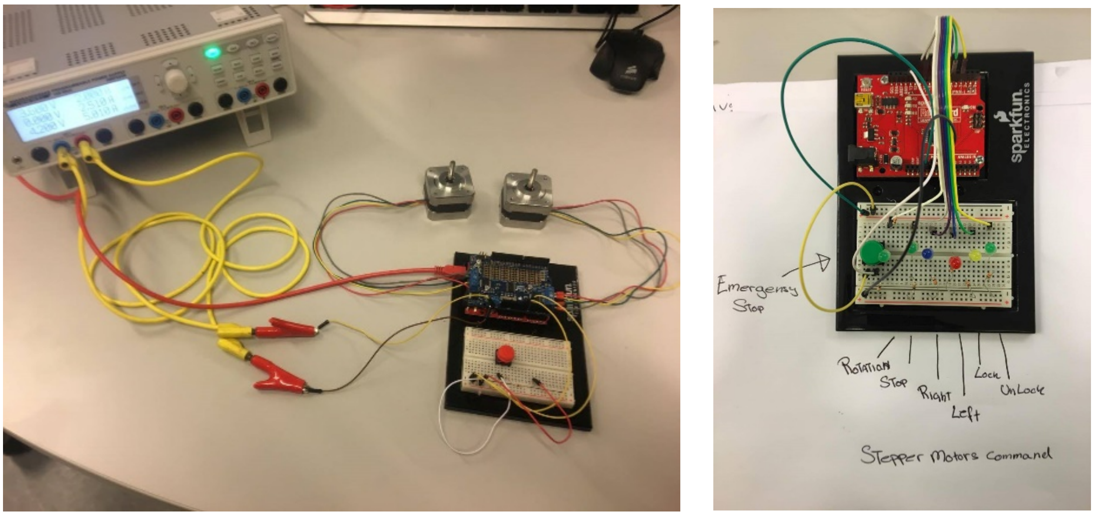
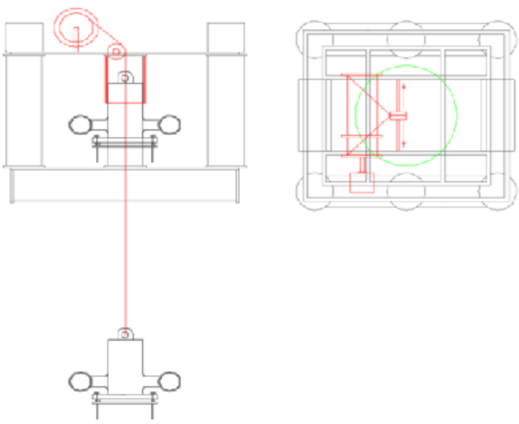
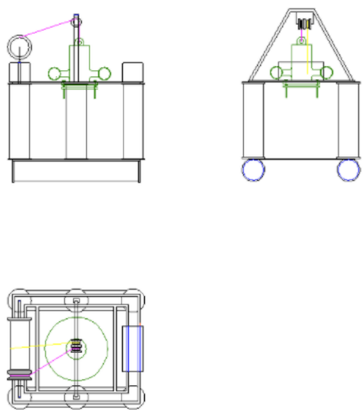


Figure 4-1 Testing Arduino

5 RESULTS

We'll split this chapter in the main issues with this project, focusing on one at a time, an connecting them all at the end. There have been a lot of different ideas for the design of the winching system. An alternative was to install a A-frame. This would have caused a reduction in dragforces but it would have resulted in a high detailed and time consuming system. We concluded that it would be better to place the ROV inside the platform. This because it requires less torque if it's always beneath sea-level, and also it makes it makes it easier to install as well. *The main design alternatives are attached [Appendix 12 & 13].*





5.1 THE WINCH

The winch was the obvious main task of the project, making it the part which we spent the most time working on. We decided on an early stage to try making the winch extraordinary, as we had the opportunity to 3D-print parts.

The main diameter of the winch drum was decided to be Ø150. It was calculated that this diameter would be sufficient with the estimated length of cable we had at that stage. Later, the diameter could, and maybe should be changed, but having come as far as we had, we decided to stay with the initial Ø150. The length of the drum varied through the design process, from approximately 170mm to 300mm at most. We ended up with a drum measuring in at 297mm, having an effective drum length of approx. 273mm. The main reason for the increased length is the slip ring fitted inside the drum.

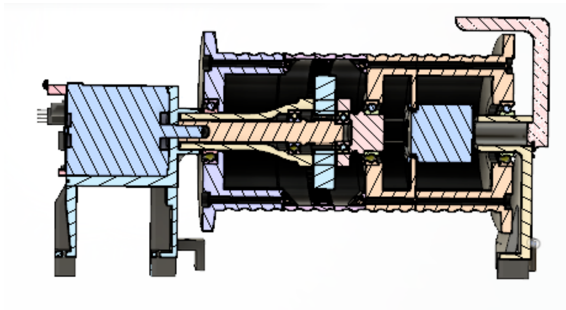


Figure 5-1 Winch in Fusion

As seen in the picture Figure 5-1, there are tracks in the drum, for leading the wire. The size of these tracks is decided by the size of the wire, which in this case is ½" OD.

Having decided on the drum diameter gave way for constructing the transmission. We decided on constructing a planetary gear inside the winch drum. A few weeks into the project we got a motor for driving the winch. The motor delivers a holding torque of 7 Nm. This torque is quite a lot, but still, we would struggle with the weight of the ROV in air. In water, however, the ROV would easily be lifted. The parameters of the gear became as follows:

	Ring gear [R]	Sun gear [S]	Planet gears [P]
Module [mm]	2	2	2
Number of teeth	70	12	29
Diameter [mm]	150	24	58

Table 5-1 Gear Data

This gave us a transmission as illustrated to the right. Here, the planets of the gear are fitted with bearings (see parts list), driving the gear with the planets in standstill positions. The gear ratio is 5.83.

Using the theory from chapter 2.5, we can easily determine the number of steps the stepper motor attached has to do to let out e.g. 1m of cable from the designed winch.

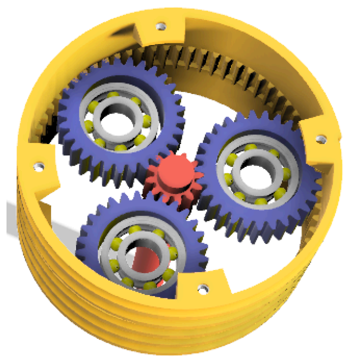


Figure 5-2 Gear inside winch drum

In this case we get

$$N_{motor} = G_r * n_c * S$$

We have S=800, G_r=5,83 and

$$n_c = \frac{1m}{0{,}47m} = 2{,}12$$

This gives us

$$N_{motor} = 5{,}83 * 2{,}12 * 800 = 9923{,}4$$

Deciding the gear and achieving the gear ratio gives us the desired motor speed (revs/min). To ensure a good lowering of the ROV, we set the initial speed of the lowering to .05 m/s. This is calculated with respect to the buoyancy and weight of the ROV. The calculations are attached [Appendix 2].

Submerged Velocity	**c**	0.05	m/s
Rotation speed	**w**	0.67	1/s
Rotation speed	**r**	6.37	rpm
Torque from cable	**M**	9.49	Nm

Table 5-2 Hoisting data

The parts on the side of the drum in Figure 5-3 are designed to stop the cable from climbing on the side of the drum. This had to be made separate from the drum because of the maximum possible print size in the 3D-printers.

Besides the gear, the drum also includes a slip ring. These two systems decide the design and size of the drum. The biggest challenge while designing the drum was to have the drum rotating, the slip ring fitted in the correct way while also locking the planet gears in position; all at the same time. This lead to many hours of designing and re-designing, and ended up as the following pictures describe:

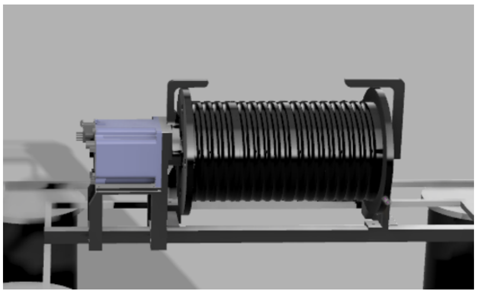


Figure 5-3 Assembly of winch parts

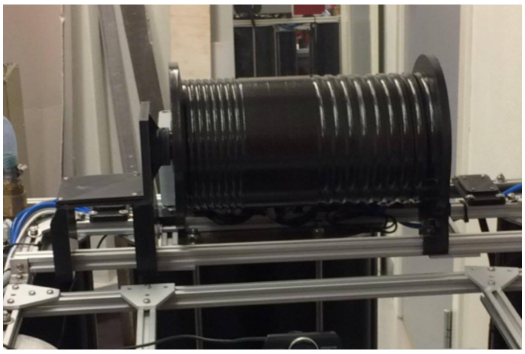


Figure 5-4 Most of the winch mounted on the platform

Figure 5-5 Platform with all parts ready for testing

Attached to this report are illustrations of the finished designs.

5.2 CABLE POSITIONING TOOL

It's highly necessary to install a wire positioning tool to prevent the angle between the pulley and drum to be more than 4 degrees. This is derived from a rule of thumbs, saying that the cable should be within 4 degrees of the perpendicular of the drum. As mentioned before the tracks will play a major role leading the cable in the desired direction. In order to lead the cable, a pulley with possibilities of moving horizontally was installed in front of the drum. A linear bearing is placed inside the pulley to ensure that it slides smoothly. The bearing comes with a flange which will be attached to the pulley. The shaft passing through the bearing is supported on both sides with shaft blocks.

Figure 5-6 Cable positioning tool

5.3 SELF-ALIGNED LOCKING OF THE ROV

When the ROV is in standby mode and not in use it will be locked and secured on the platform for further transportation managed by the platform. This requires a more stable and aligned connection between the platform and the ROV than just the cable itself. By controlling it as one whole unit simplifies the transportation on longer horizontal distances and also the hoisting operation up and down from deck on a bigger vessel. By placing the ROV inside of the platform increases the protection of the ROV when in standby and also brings the ROV closer to the gravity point of the platform. In case of power outage on the platform the locking house should keep the ROV aligned and secured to the platform due to mechanical holding forces. With that in mind, the chosen design is preferred.

Since the ROV has a circular shape, the shape of locking house is also circular to give a good connection of the ROV with the rest of the platform. The design of the lock keeps the ROV in holding position both in horizontal and vertical direction. Therefore, there is no need for further breaking systems to be installed to hold the weight of the ROV when the winch is in standby.

As shown on *Figure 5-7* below, the locking house is placed more to the left side of the complete structure. When the hoisting operation of the ROV is complete, the cable will be positioned at the left side of the drum. Explaining sketches of the mechanisms, different solutions and the total operation of locking and unlocking the ROV is described in *Appendix – Locking mechanism.* Some calculations were made to ensure that the system is sufficient for the certain operation. *Both calculations and a complete list of parts is available in the Appendices [Appendix 3 & 10].*

Figure 5-7 ROV locking tool

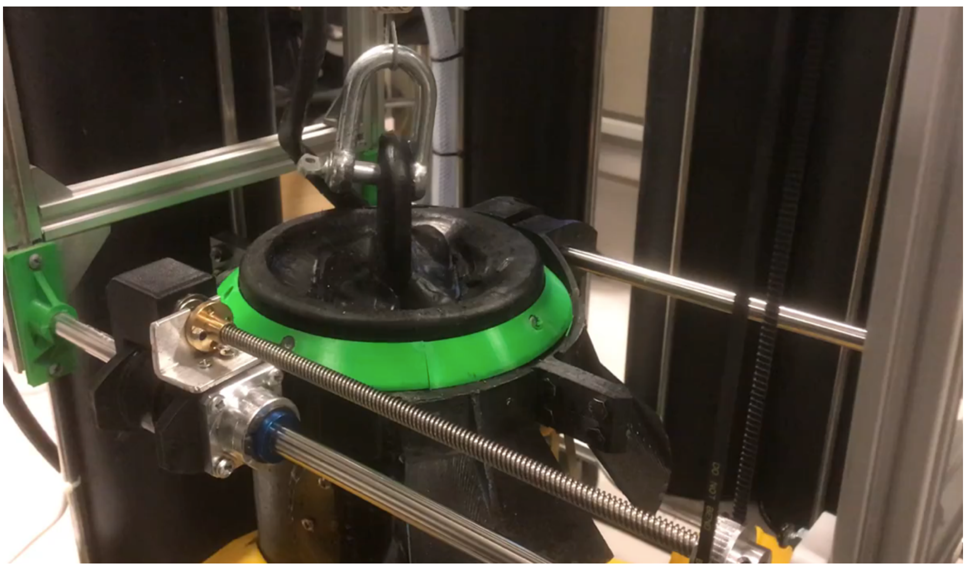


Figure 5-8 ROV locking tool installed

5.4 INCREASING THE BUOYANCY

As mentioned, the winch system will at best nearly sink the platform when attached. Therefore, we have to increase the initial buoyancy of the platform. This is done by adding more pipes to the platform.

Using formulas for calculating weight and buoyancy, we get the force either keeping the platform afloat or sinking it.

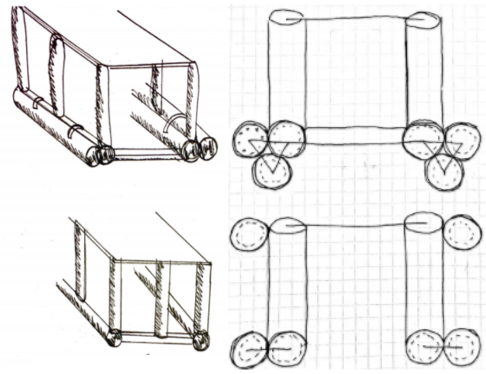
$$F = -mg + \rho V g$$

A negative force F means a sinking platform.

From the bachelor thesis of the platform, there is no definite volume of the platform to base our calculations on. It seems like the volume (at worst case) is .132 cubic metres. With a measured weight of 115.5kg, this gives us

Weight before	115,5	kg
Volume	0,132	m3
Total buoyancy	**194**	**N**

Table 5-3 Buoyancy before starting the project



We decided that we would like to increase the buoyancy force further by adding more pipes. This gives the stability system of the platform a possibility to fill it with more water while stabilising the platform, making it work better.

Figure 5-9 Buoyancy pipes added in vacant spaces

We had some different solutions to this subject. For example, adding extra pipes on the side and on the bottom of the platform. At the time, it seemed like a good solution to add two pipes on each side of the platform, of course this will result in extra drag-forces while driving the platform, but in return it is easier to attach. Adding the pipes at the vacant spaces at the ends of the platform (as shown in figure 5-9) gives the platform better buoyancy, in addition to not affecting the stability. The final weight of the platform is measured at 156 kilos, giving a (estimated) final initial buoyancy of (+)282 N. This ensures that the platform would not sink, and that the systems already built for the platform should work as before (if they were not constrained to an absolute buoyancy, which is doubtful).

Weight after	156	kg

Added Volume	0,048	m3
New Volume	0,180	m3
Total buoyancy	**282**	**N**

Table 5-4 Buoyancy at the end of the project

The arrangement of the extra pipes was manufactured by the workshop here at NTNU in Aalesund. *The drawings for the manufacturing are attached to this report [Appendix 7].*

5.5 CABLE MANAGEMENT

The cables to and from the ROV proposes a bit of a problem to the winch. The fitted power cable was a 4x4, and with an additional CAT5-cable the total cable dimensions were quite big. We decided to try and reduce the total cable dimensions, and fitting them all into one, to get a cleaner look of the cables and easier operation with the winch. We also added a steel wire for lifting the ROV, so that the power- and connection cables wouldn’t have to deal with the forces acting on the winch from the ROV. A total of two power cables, one CAT5-cable and a Ø2 steel wire were all fitted inside a standard ½” garden hose. This lead to the dimensioning of the tracks in the winch drum, as mentioned earlier. The finished cable ended up being 7m long.

5.6 FLOWCHART

This is a Flowchart showing the new implemented winch system. The flowchart shows where the equipment is located, the equipment which is with the lines are on board the SeaFarm and the equipment outside the lines and connected whit Wifi are onshore alongside the winch operator. The Odroid on the SeaFarm works like a master while the arudino acts as a slave.

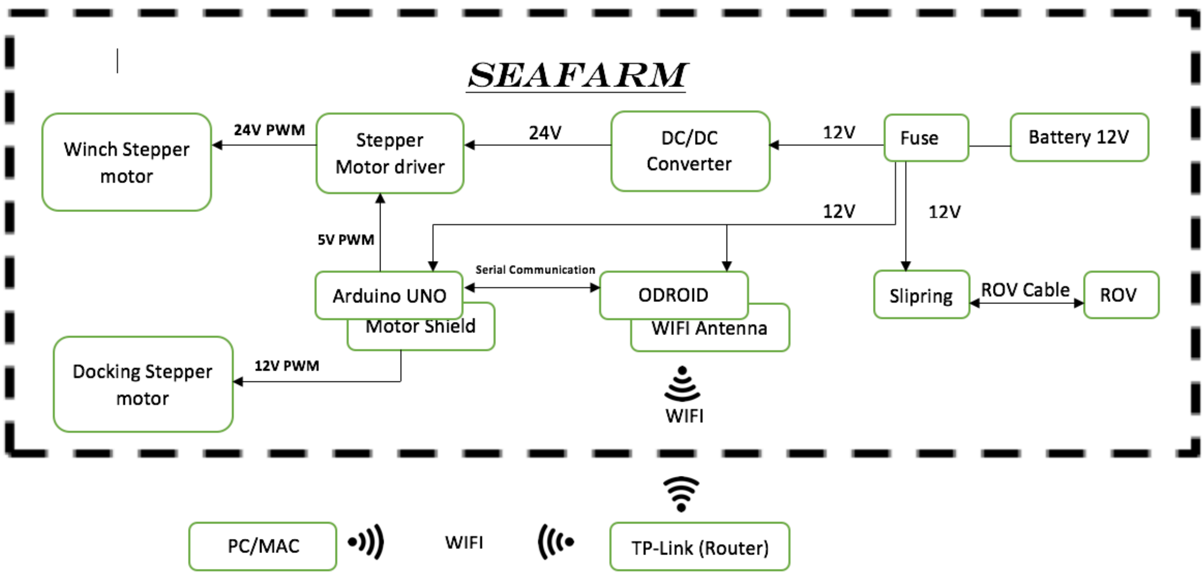


Figure 5-10 SeaFarm flowchart

5.7 PROGRAM STRUCTURE (JAVA)

Java code is developed based on a server client solution that sends TCP packets over ethernet with IP addresses as a reference point.

Here you will get a simple GUI where you enter the IP address and number of port you select and communicate through.

The odroid starts up a server on the platform. Once this is done, you can connect to the server with a communication client that we have called WinchController. Here you have the ability to execute commands that trigger the various functions mentioned in the microcontroller program. These different features are triggered by simple commands that are typed into the command window in the Winch Controller.

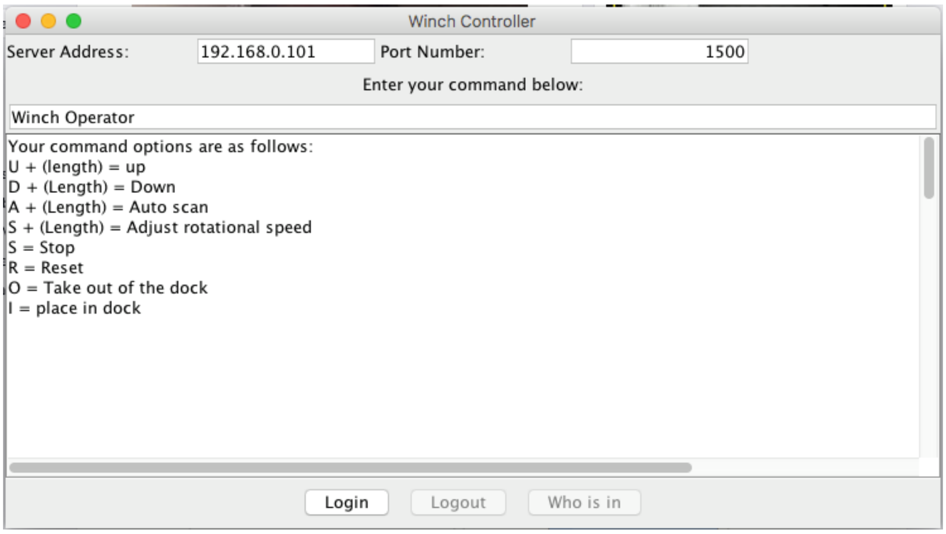


Figure 5-11 Program structure in JAVA

Figure 5-12 Command and event window

5.8 PROGRAM STRUCTURE (ARDUINO)

The program structure of the arduino is constructed using a method called Switch Case. There the program has multiple cases and choose between.

The different cases have the names: Up, Down Stop, Reset, Lock, UnLock and ScanMode.

Up and down mode requires you to enter how far you should move up or down.

Stop is used as an emergency stop or regular stop.

Reset is a function you use for power failure or other system failures, which means that the winch does not know where it is located. In this case, the ROV will be driven to a known point, making it able to reset itself.

Lock means it takes the ROV out of the water to place it in the docking station.

Unlock means that the ROV is taken out of its docking station and placed in the water ready for use.

ScanMode is used to drive up and down from the given position where you choose the amount of scanning you can drive the platform while scanning up and down underwater.

5.9 SLIP RING

The slip ring is ordered from Hong Kong with desired specificataions. We weren't able to use a standard, small slip ring, because of the power required by the ROV from the platform. This lead to the slip ring being a special component for the project. It is capable of 25A per ring, having two rings inside. It is IP51, meaning it is not waterproof. Rather than ordering the slip ring waterproof, making it a lot more expensive, we decided we would make sure that the drum doesn't let water inside. The slip ring drawing is attached with the specifications given from the supplier [Appendix 9].

5.10 CONNECTING IT ALL UP

With all parts mounted, and the software installed and ready for use, we've made a winch capable of hoisting the ROV up and down, and locking it in standby when necessary. The winch runs by itself as things stand now, but with an effort to connect all softwares, the SeaFarm could be more or less ready to do its work.

5.11 TESTING

We got the platform in the sea a few days before deadline to test the winch and the mechanisms attached. Having installed the parts on mostly one side of the platform, we had to stabilize the platform by adding weight, as we had not got the stability control (ballast pumps) up and running.

The test showed that the winch worked, and had no problem hoisting the ROV up and down. Unfortunately, we didn't get the time to set up the platform at "even keel" to fully test the wire leading tool and the locking mechanism. This was because of a leaking pontoon, addressed in the "further development" chapter of this report.

Figure 5-13 Lifting the platform into the sea

6 DISCUSSION

This project had a lot of issues to deal with. Making a winch especially for this platform was a major challenge. We designed, calculated and tested the winch system. The size of the project, unfortunately was a bit too big for fitting in just one (short) semester. Having made this product and fitted it to the platform, we now have a working system, only needing work to collaborate to be seen as finished.

6.1 MISSING PARTS

Because of the time required to complete this project, some parts have not been finished. These parts are discussed here, and should probably be implemented in the next phase of the SeaFarm-project.

6.1.1 Emergency brake on the winch

Because of the risk of power failure, an automatic form of braking on the winch should be mounted. Our proposal is to make some kind of gear on one of the sides of the winch, with a lock attached to a motor, always holding the lock away from the teeth. If a power failure occurs, the motor will shut down, and the lock will go into the teeth, effectively stopping the winch.

6.1.2 Load cells

We have begun to assemble a load cell, which was unfortunately not completed. This because of time and we were having trouble with the amplifier we had bought. This caused too much noise to the arduino, which caused the winch to stop without being necessary.

The measuring bridge we had bought had received good reviews but the amplifier was somewhat inaccurate, this should be corrected. This will prevent breakage of the wire or break the winch if the ROV should get caught under water.

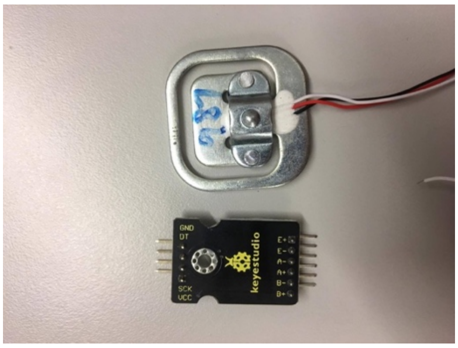


Figure 6-1 Load Cell

6.1.3 End switch

End switches have not been fitted due to changes in construction before testing. This requires a change of bracket where the end switch is located. The switch is placed over the pully. The ROV cable has a "swelling" at the end that wants to detect when the cable has reached its end point.

6.2 DECISIONS

Following, we’ve discussed a few key points we’ve met during the project, to reflect our decisions:

6.2.1 Planetary gear VS worm gear

Our motivation to model a combined planetary gear and drum is to make something new and unique, and further determine how good this concept works. Perhaps, in retrospect, we see that it would have been better to install a worm gear instead of a planetary gear. This would most probably cause a lower winch velocity. In return, the worm gear delivers a higher output torque. It requires less space inside the drum and to a certain extent it will cause a self-braking mechanism. In a case where we would mass-produce the winch, a worm gear would be sufficient.

6.2.2 Using 3D printing instead of traditional, steel manufacturing

We decided to use 3D-printing mostly because of the great possibilities with design. 3D-printing is also superior when it comes to price and weight, even though 3D-printing requires thicker and more solid parts. The PLA, however, comes with a few drawbacks. As of now, 3D-printing isn't as precise as standard manufacturing, and we see us having to adjust parts to get them to fit together. The PLA isn't as strong as metals, and with 3D-printing, we often get areas where high stresses occur and would break the parts.

6.2.3 Winch design

With the platform having a very high draft to begin with, we've decided to make the winch as close to the CoG as possible. This is mostly to reduce the heeling moments introduced if we were to lower the ROV with an A-frame over board of the platform. The winch drum is designed with a diameter of Ø150mm to ensure that the cable would stack only at one layer. Also, the size of the drum fits with the rest of the platform.

6.2.4 Putting the ROV inside the platform, instead of on top

At first, it was proposed to put the ROV on top of the platform when in standby-mode. We discussed it and proposed a design seeing the ROV "inside" the platform. This means that the ROV will be mostly submerged in standby, when the platform is at sea. A submerged body will be significantly lighter than a body in air, meaning less force acting on the components. With the ROV in a relatively low position, the CoG of the total mass lowers, making the platform more stable. The positioning of the ROV also makes for a slicker design of the winch, not needing e.g. an A-frame.

6.2.5 Wi-Fi / Bluetooth

We've chosen to connect the parts with Wi-Fi because of the range that Wi-Fi offers, compared to Bluetooth. Also, Wi-Fi is the more stable type of connection of the two alternatives.

6.2.6 Slip Ring

As the ROV requires a lot of power, a regular, small slip ring wasn't quite enough for this project. The most common slip rings found were not good enough because the ROV needed at least 25A. This is more than what you can get from most regular slip rings. We ended up ordering a large slip ring, delivering the power we required. An alternative to ordering this slip ring would be to make one ourselves. This would probably result in a not-so-good result. Therefore, ordering the slip ring became our choice.

6.2.7 Motors

Initially, we thought of using brushless DC motors, because they use less power. We decided to use steppers motors because they're easier to control, and gives us a more precise result. Also, the stepper motors have a holding torque, making them able to hold masses. For the winch, which required the most powerful motor on the project, we decided to go with a motor already in place at the university. This motor is a DC stepper motor, and fits our requirements.

6.2.8 The ROV locking

As mentioned, we decided to lock the ROV inside the platform in standby-mode. An initial alternative, before deciding on the winch was to make a standing platform on top of the platform, if the ROV were to be locked on top of the platform, instead of inside. We also discussed the possibility to use a rotating flat bar or similar into the ROV to lock it, instead of the "clamps" or locking house now designed and manufactured. The current design ensured that the ROV will be placed near the center of the platform, where the cable starts on the drum. It also gives good releasing of the ROV. The current design creates a good and stable connection between the platform and the ROV, both in vertical and horizontal direction. The locking part installed on the ROV should maybe be placed further in the middle of the ROV to stabilize even more. To do this, changes to the ROV itself should be made. The lock holds the weight of the ROV without any help from the winch. The total concept of this design was tested and works as it should. The design became more complex than first planned, but also added a few more features like holding the weight of the winch and holding it all around the shape of the ROV with precision.

6.2.9 The final result

During this project, we've made many different choices. On some points, we've decided on the cheapest, on others the most teaching, and on some, we went for the best. In the case with the motors, for example, we got the motors here at the university, making it the easiest choice, as long as they fit our requirements.

7 FURTHER DEVELOPMENT

As this project is a part of a larger, ongoing project at the university, we would like to sketch the outline of the tasks that had to be solved for a complete SeaFarm. The project we've now gone through has seen a winch being built, and parts ordered for a connection of the ROV, via the winch and to the platform. More specifically, the following tasks still rest on the project:

7.1 CONNECTING ALL PARTS OF THE SEAFARM

This should be the main task of the next project on the SeaFarm. As things stands now, all parts are ready to connect, but the programs of each part aren't compatible with each other.

7.2 CHECK THAT ALL PARTS WORK CORRECTLY

Checking that all parts work correctly as described in this report is necessary to ensure the SeaFarm working as it should. We experienced a leak in one of the pontoons carrying batteries, and they may have to be replaced because of this. Also, checking that the locking of the ROV work is important, as this is a fragile part when it comes to precision. Note that we will try to leave the SeaFarm in the best state possible. It should also be noted that one have to ensure that all parts are waterproof.

8 CONCLUSION

The winch which is now mounted on the platform consists of three major parts, together with a few other modifications. A simple winch, with a gear inside, a linear pulley, a self-aligning locking tool is the main parts of this project. Through 3D-printing mostly, the winch is now made more or less of plastics. This opens up to a new way of producing parts for projects like this. It makes for a possibility to construct advanced geometry and advanced, minimalized parts. We've also, with the 3D-printed gear, proved that it is possible to construct working gears in a 3D-printer. This applies only when the forces acting on the gear are relatively small.

The Scope of Work is more or less fulfilled, with a few drawbacks, as things takes more time than assumed. We've learned how to collaborate in a group, working together to make a product consisting of parts from more than one field within engineering.

In conclusion, the project was a bit too large to fulfil all ideas proposed at the beginning. Even so, the project has lead way to complete the SeaFarm. As of now, the only thing left to complete the SeaFarm is to connect all parts together to make a functioning product.

9 REVISIONS

In this updated document, all parts of the text added has been coloured red. Illustrations and pictures added has not been given a figure-number, as this was difficult in the text-program. All appendices have been numbered, and appendices referred to in the report are referred to with the desired number.

10 REFERENCES

[1] https://en.wikipedia.org/wiki/Industry_4.0 (26.10.17)

[2] https://ultimaker.com/download/67934/TDS%20PLA%20v3.011.pdf (26.10.17)

[3] https://cdn.sparkfun.com/datasheets/Dev/Arduino/Boards/Redboardv1.pdf (23.11.17)

[4] https://cdn.instructables.com/ORIG/FCN/YABW/IHNTEND4/FCNYABWIHNTEND4.pdf (23.11.17)

[5] http://www.electronics-lab.com/wp-content/uploads/2016/05/4.5A-Bipolar-Stepper-Motor-Driver-TB6600.pdf (23.11.17)

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[7] https://magazine.odroid.com/wp-content/uploads/odroid-xu4-user-manual.pdf (23.11.17)

11 APPENDICES

Appendix 1 - Scope of work

Appendix 2 - Calculations

Appendix 3 - Parts List

Appendix 4 - Assembly instructions for the winch

Appendix 5 - 3D-models of parts

Appendix 6 - Drawing of pipes arrangement

Appendix 7 - Status reports

Appendix 8 - Time Schedule

Appendix 9 - Slip Ring drawing

Appendix 10 - Locking Mechanism

Appendix 11 - Motor data

Appendix 12 – Winch Design proposal no. 1

Appendix 13 – Winch design proposal no. 2

Appendix 14 – Motor considerations

Innføring i Mekatronikk
IP304814

Project Mechatronics

SeaFarm – Simple Winch

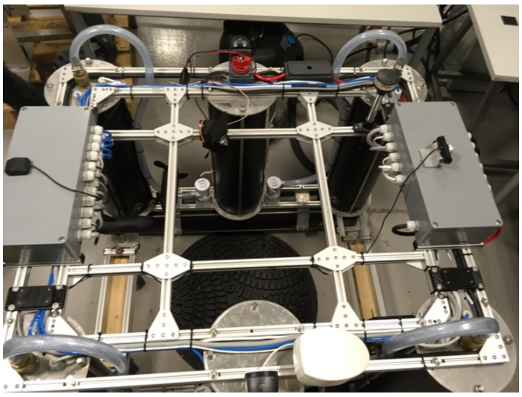
Date: 22.09.2017

Project Name:

Simple Winch for the SeaFarm

Project Introduction:

The SeaFarm is an on-going project at NTNU in Aalesund, Norway. The project aims to build an efficient, cheap and reliable SeaFarm for inspection of underwater environment, especially within the fish breeding industry. Today, the SeaFarm consists of two main parts, to be attached together to make the farm complete.



The two parts, a platform and a ROV is to be connected to form a complete working system to inspect the fish breeding nets.

The platform measures approximately 1 m x 0.6 m x 1 m, and is made of affordable and common materials, which makes it both cheap and relatively small. The platform has a type of ballast-water system, making it able to adjust to heel and trim. It is also equipped with thrusters, making it able to move in the water. The platform weights 115 kgs.

The other part, a ROV is made with three thrusters, giving it the ability to move in all directions in water. It is fitted with a camera for inspecting, and weights approximately 13 kgs.

Project Task:

This semesters project in the subject “Innføring I Mekatronikk” is to attach the ROV to the platform with a simple winch.
The project task includes:

- Making the winch and power it with the batteries on the platform
- Assure the ROV is not disturbed by heave on the platform
- Locking the ROV in position when the SeaFarm isn’t in use.
- Holding the platform at a given depth in the water.
- The ROV is to be lowered to a depth of 10 m.

This task also makes for a few adjustments on the existing parts to be done:

- Collecting the cables of the ROV (CAT 5 and power supply) into one, with an additional steel wire for the winch.
- Improve the initial buoyancy of the platform, as is would sink with the ROV in place with the current design.

Innføring i Mekatronikk
IP304814

Calculations and data

Simple Winch

Date: 23.11.2017

Calculations ROV			
Gravity force	**G**	126,5	N
Boyancy	**B**	86,6	N
Drag force	**D**	0,1255	N (negligible)
Sum Force	**Fs**	40,0	N

Calculation drum			
Safety factor	**Sf**	1	-
Submergerged Velocity	**c**	0,05	m/s
Rotation speed	**w**	0,67	1/s
Rotation speed	**r**	6,37	rpm
Torque	**M**	9,49	Nm

Calculation gear			
Ratio	ra	5,83	-
Torque out	Mgo	9,49	Nm
Torque in	Mgi	1,627	Nm

Calculation axle			
Motstandsmoment	Wxa	0,0000005	m^3
Polart motstandsmoment	Wpa	0,0000010	m^3
Bending momentum	Mb	-	Nm
Torsion momentum	Mt	7	Nm
Bending tension	Sigma B	-	N/m^2 (negligible)
Torsion tension	Sigma T	7256402,86	N/m^2
Rotation speed	Arpm	37,2	rpm

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General data			
Gravity-constant	g	9,81	m/s2
Density water	psw	1025	kg/m3
Density PLA	pp	1250	kg/m3

Masses			
Mass, drum	md	2,329	kg
Mass, motor	mm	3,204	kg

Data Motor			
Max torque	Tmax	7	Nm
Max rotation speed	Rmax		Rpm

Data Axle			
Axle 1 diameter	Ad1	0,017	m
Axle 1 length	Al1	0,0894	m

DATA ROV			
Mass	m	12,9	kg
Volum	V	0,008611	m3
Eff. area	A	0,071	m2 (Estimate)
Drag coeff.	cf	1,38	-
Free fall velocity	co	0,89	m/s
Submerged Velocity	c	0,05	m/s

DATA Drum			
Diameter drum	dd	0,15	m
Length drum	ld	0,297	m
Eff. lenght drum	eld	0,28	m

Data gear			
Module	mr	2	mm
Number of teeth in ring gear [R]	zr	70	
Number of teeth in sun gear [S]	zs	12	
Number of teeth in planet gears [P]	zp	29	

DATA cable			
Length wire	lw	7	m
diameter wire	dw	0,002	m
Length com.cable	lcc	7	m
diameter com.cable	dcc	0,008	m
Length el.cable	lec	7	m
diameter el.cable	dec		m

Innføring i Mekatronikk
IP304814

Parts List

Simple Winch

Date: 23.11.2017

	Material	Type	Price	Weight [kg]	Note
Winch					
Drum	PLA	3D-printed	kr 1 000,00	2,329	Price is estimated, and includes material for all the winch parts. Weight is all components on winch
Bearings	Stainless steel	4 x 6203, 3 x 6007, 1 x 6004	kr 487,20	0,748	
Circlip	Stainless steel	3 x Ø17, 1 x Ø20, 1 x Ø35	kr 100,00	-	
Slip ring			kr 2 566,00		
Motor	-	PD86-3-11180 stepper motor	-	3,138	Expensive, but we got it at NTNU
Gear	PLA	3D-printed	-	-	Planetary gear, weight included in "Drum"
Cable					
Steel wire	Steel, galvanized	Ø2, 25m	kr 149,00		
CAT5					
Power cable		2x 2mm^2			

Electrical components					
Arduino		UNO	kr 250,00		
Dc motor Driver		Two-phase Stepper motor driver	kr 150,00		
Router		TP-Link	kr 500,00		
Motor Shield		Adafruite	kr 100,00		
End Switch					
WIFI Antenna		Odroid wifi antenna	kr 99,00		
DC/DC converter		Vanson	kr 614,00		
Odroid 4XU		Odroide	kr 790,00		
Buoyancy					
Pipes	PVC	Ø160x5	-	10	Weigt is estimated, and is total for all parts of buoyancy
Aluminium plates	Aluminium	t=5mm	-	-	
Axles	Stainless steel	Ø10, threaded at ends	-	-	
Wire positioning Tool					
Block	PLA	3D-printed	-		
Pulley	PLA	3D-printed	-		
Pulleyblock	PLA	3D-printed	-		
Axle	Stainless steel	Ø12 x 700	kr 210,00		
Linear bearing	Anodized aluminium	Flange housing FJUM-01/31	kr 400,00	0,042	

ROV Locking Tool					
Axle	Stainless steel	Ø12x400 x 2, Ø10x224 x 1	kr 220,00	0,854	
Linear bearing	Anodized aluminium	Flange housing FJUM-01/31 x2	kr 800,00	0,084	
Motor	-	Nema 23 SN: 57BYGH420	kr 111,00	0,7	
Springs	Stainless steel	Ø6x20 x 2	-	-	
Ball bearing	Steel, syntetic rubber	6000 2RS	kr 39,90	0,019	
Frame	Aluminum	20x20 x 4	-	0,576	
Wire	Nylon	Ø0.25	kr 99,90	-	
Locking house	PLA	3D-printed		0,76	
Leaders	PLA	3D-printed			
Mounting brackets	PLA	3D-printed		0,08	
Pulleyblocks	PLA	3D-printed	kr 250,00	0,03	
Wire leading assistant	PLA	3D-printed		0,005	
Motorplattform	PLA	3D-printed		0,099	
Hood	PLA	3D-printed			
Total			**kr 8 936,00**	**19,464**	**kg**

PLEASE NOTE: This list covers the main parts used in the project. All small, standard parts also used are stainless steel or aluminium.
Both price and weight is estimated or measured,and may no be 100% correct.

Innføring i Mekatronikk
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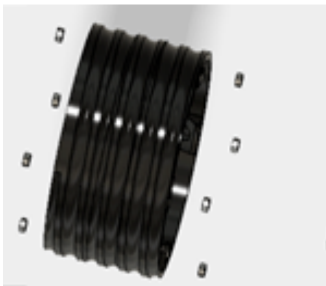
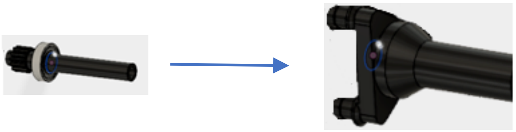
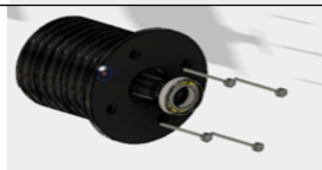
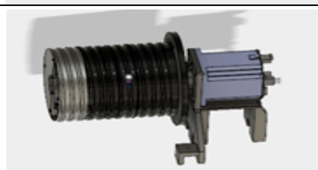
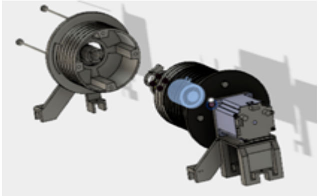
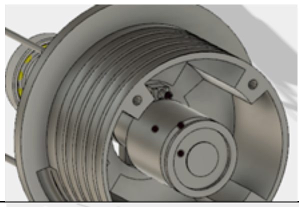
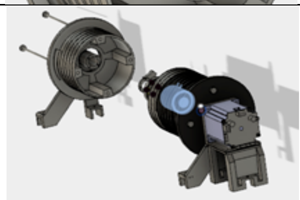
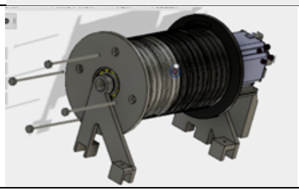
Mounting of the winch

Simple Winch

Date: 23.11.2017

- Place the nuts inside the drum. Screws will later on be attached to these.	
- Attach two of the planetary gears with 6203 inside on the triangular support. - Put the sungear-axle with 6004 bearing inside the triangular support. - Insert the components to drum. - Put the last gear into the drum and on the triangular support	
- Attached the triangle support to the second triangular component. Note! There is a 6203 bearing inside the second triangular part which is not shown in the figure.	
- Attach a 6007 bearing at the shaft of the second triangular part.	
- The finished module will look like this. - This is called module 2	
- Attach the drum on the motor side. - This is called module 1	
- Insert the M5x 80 screws. - Insert 6007 bearing	
- Attach the motorsupport - Attach motor - Attach module 3 of the drum to the assembly. This contains a bearinghouse. (grey-part)	

- Insert mounting bracket to the last module (module 4). This is attached with 4 m4x10 screws. The slipring will be attached to this bracket later.	
- Attach slipring to the bracket	
- Assembly the drums	
- Attach 6007 bearing - Attach drumsupport 2 - Insert 4 M5 x 140 screws	

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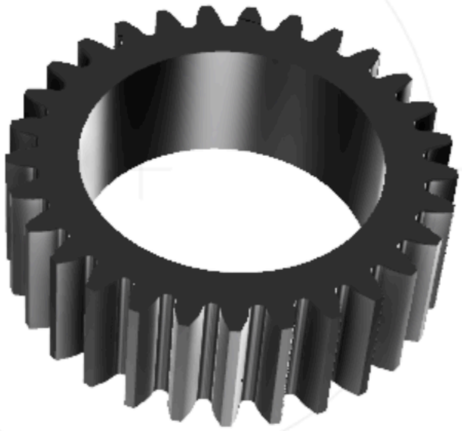
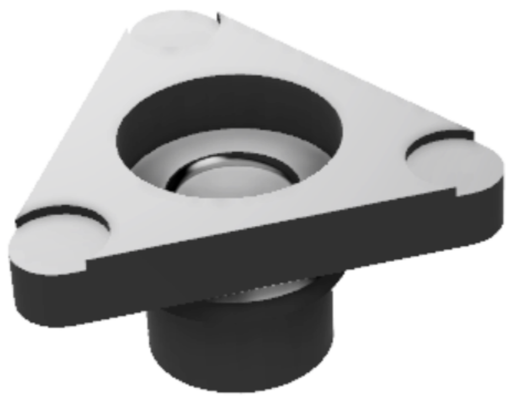
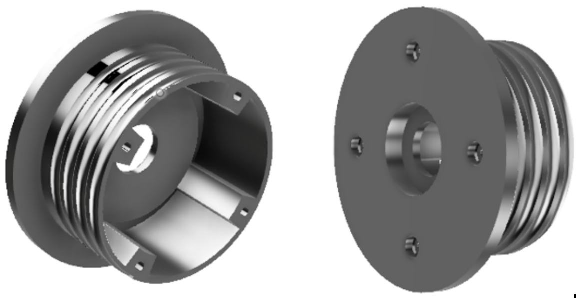
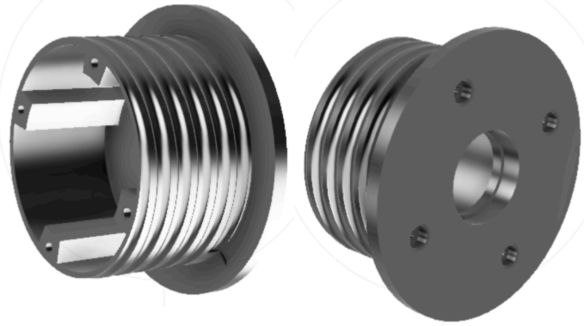
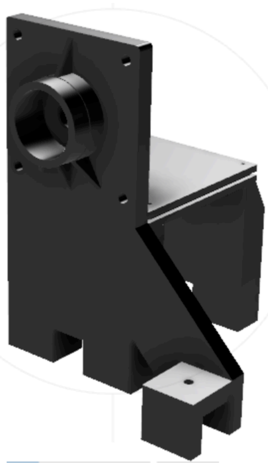
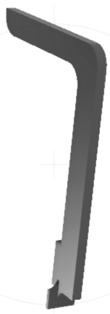
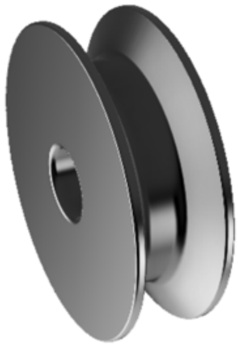
3D-models of parts

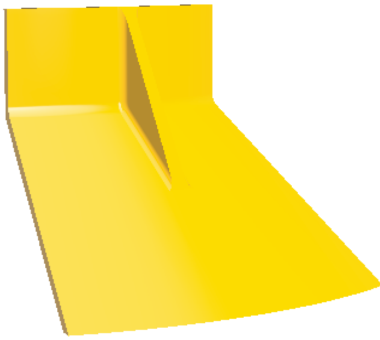
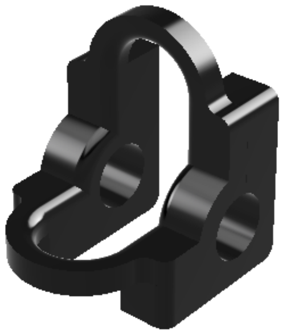
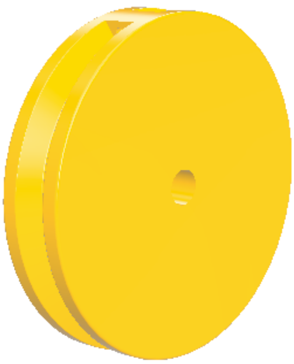
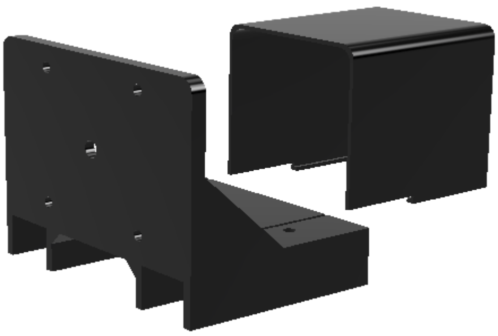
Simple Winch

Date: 23.11.2017

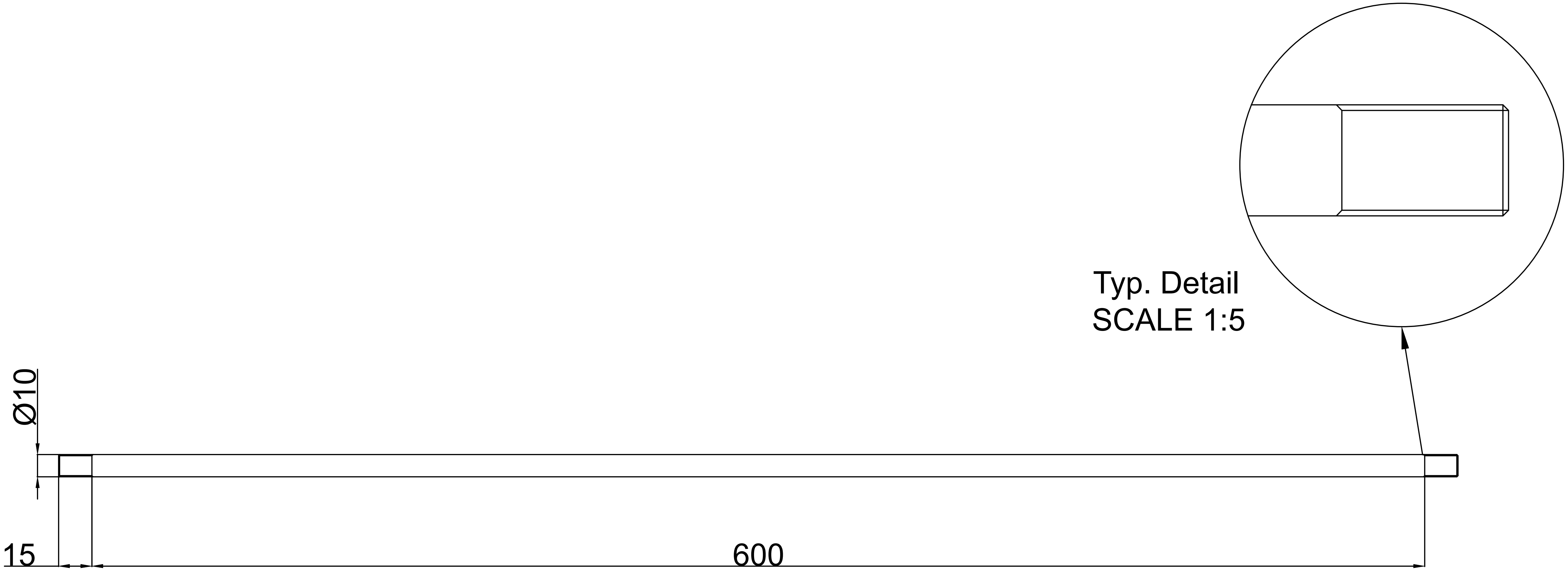
Winch	
Ø58- planet gear	**Ø24-axle with sun gear**
	
Triangle component 1	**Triangle component 2**
	
Drum module 1	**Drum module 2**
	

Drum module 3	**Drum module 4**
	
Slipring bracket	**Drum support**
	
Wireblock 1	**Wireblock 2**
	
Slipring bracket	
	

Positioning tool	
Block	**Pulley**
	
Pulleyblock	**Assembly**
	

Locking mechanism	
Locking house	**Leaders**
	
Pulleyblock with bearing 6000 2RS	**Wire leading assistant**
	
Mounting bracket 1	**Mounting bracket 2**
	
Pulleyblock for stepper motor	**Motorplattform with hood**
	

SK A3 Horizontal



Notes:
Material: Stainless steel
Threading: M10x15

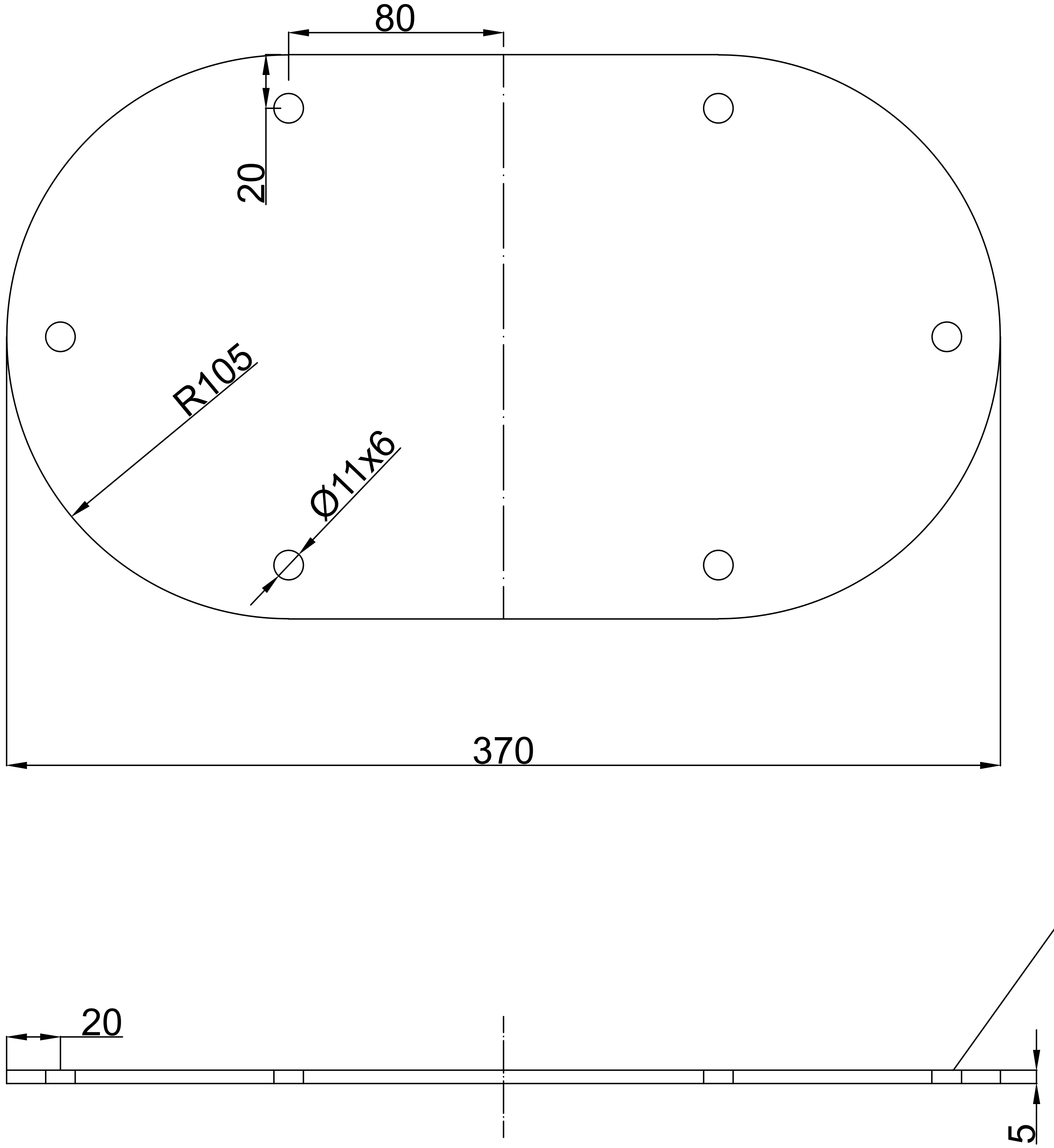
For the Mechatronics Project, 8 of these are needed.

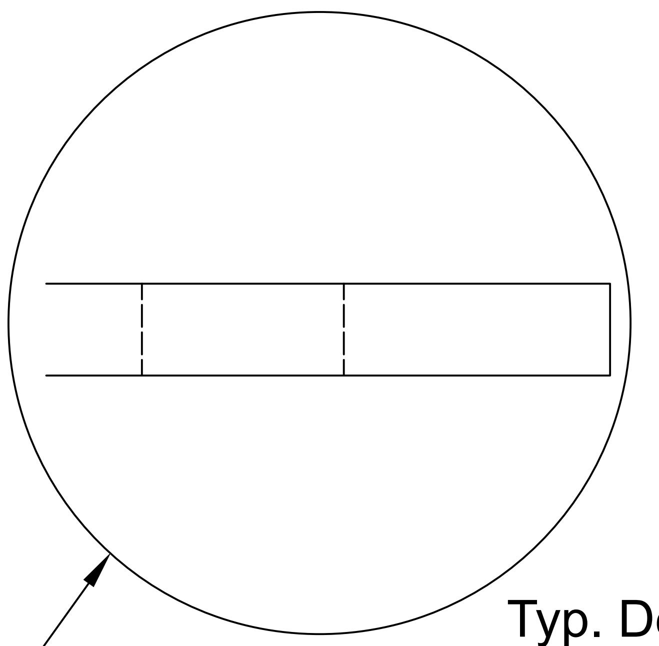
Rev.:	Description:	Rev. date:	Sign:

Customer: NTNU Aalesund		NTNU	
NTNU	Format: A3	Sheet: 1/1	
Title: Threaded round bar		101-001	Rev.: A00
Simple Winch		Scale: 1:2	Drawn. MT / Date: 02.11.17

FILE NAME/PATH: /Users/MathiasT/Google Drive/MT/NTNU/POD 3./Innføring i Mekatronikk/Project Mechatronics 2017/Drawings_Illustrations/CAD-Rør/Stang.dwg

SK A3 Horizontal





Typ. Detail
SCALE 1:5

Notes:
Material: Aluminium

For the mechatronics project, 4 of these are needed.

Rev.:	Description:	Rev. date:	Sign:
Customer: NTNU Aalesund			
NTNU	Format: A3	Sheet: 1/1	NTNU
Title: Cover for pipes Simple Winch		101–001	Rev.: A00
	Scale: 1:2	Drawn. MT	Date: 02.11.17

FILE NAME/PATH: /Users/MathiasT/Google Drive/MT/NTNU/POD 3./Innføring i Mekatronikk/Project Mechatronics 2017/Drawings_Illustrations/CAD-Rør/Lokk.dwg

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Innføring i Mekatronikk
IP304814

Status Report

Simple Winch for SeaFarm

Date: 29.09.2017

What's been done:

Established the complete task for the project. This helps us define what there is to do, and keeps us on the right track. There has also been made a time schedule, to help us get the flow we want in the project.

There's been a lot of work on the design of the winch. This includes sketching, technical drawings and 3D-modelling. These tools help us realise what parts are needed for the project. The winch design is now established, and now, the hours on the project is laid into modelling the parts for the winch.

We hope to use 3D-printing for as many parts as possible in the project. To achieve this, we are well in the way of making the parts and testing them, to get the best possible result.

To do until next status report:

Finishing up the winch design, and get parts for the building. This includes the winch frame, 3D-printed parts, the cable management and other issues related to the winch.

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Status Report

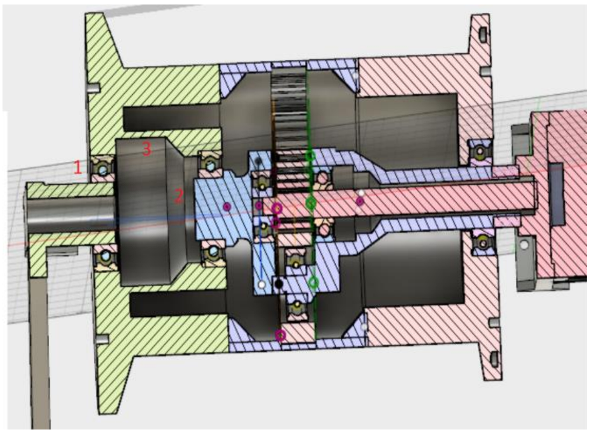
Simple Winch for SeaFarm

Date: 20.10.2017

Progress:

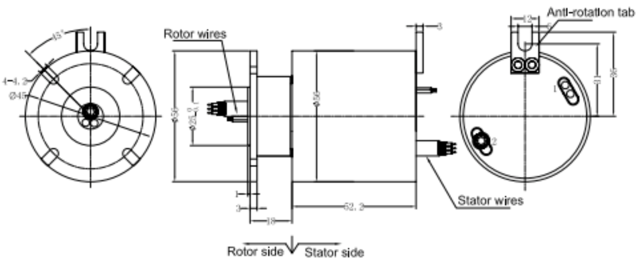
- Finishing up the 3D models. The components of the winchsystem is just about ready for printing.
- We have made some changes since the previous status report regarding the slip ring, more details later on.
- The attach and braking mechanism to the ROV is under progress and will be finished in a short time.
- Our main issue is that the printers are occupied by other students, which delays our progress.
- We have also started working on the framework attached to the platform.
- The Arduino program for controlling the winch is equipped with all the main features.
- Arduino is controlled with serial communication through USB Cable
- Test GUI in Java with serial communication with USB is created.
- Made prototype for testing Arduino program and GUI with 2 servo motors and emergency stop.
- Waiting for PWM regulator from Dealextrem sent from China 8.10. Estimated Arrival 23.10.
- The slip ring will be ordered this Friday. Delivery time time 3 days after receiving payment. But from experience they will probably take 5-7 days.

Slipring



We experienced some issues placing the slipring. We thought about installing a hollow slipring where the shaft passes through, but due to long delivery time and big costs we decided to change the design to fit a regular slipring. With current design the shaft is supported inside the drum, and the drum is supported as shown in figure 1.

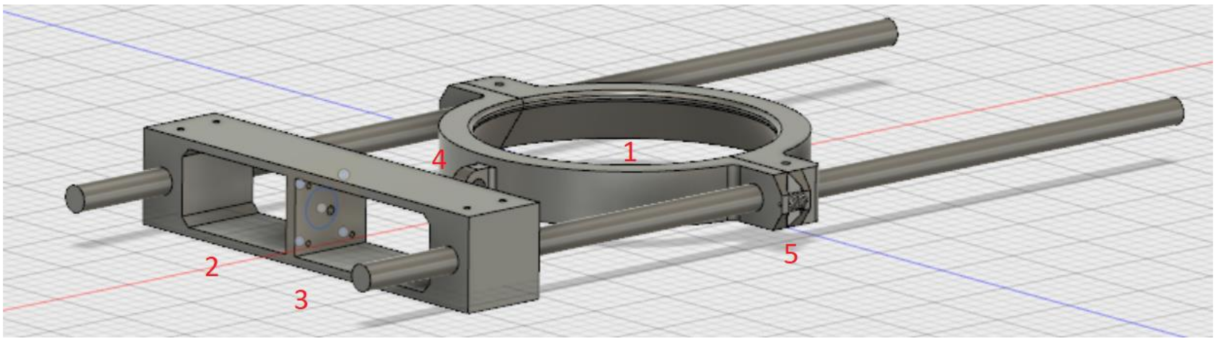
1. Drum support
2. Axle support
3. Input power cable.



Locking mechanism.

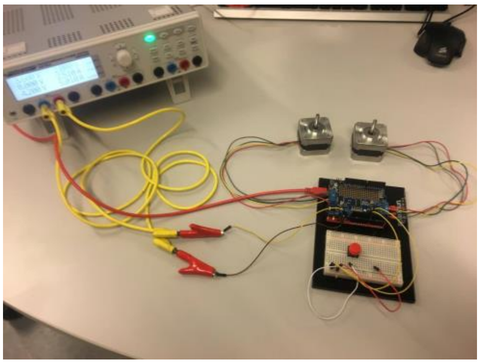
We have chosen the following solution for fixing and locking the ROV.

1. ROV attaching platform
2. Motor housing
3. Small drum attached to the motor
4. Wire from the drum, attached to the bracket

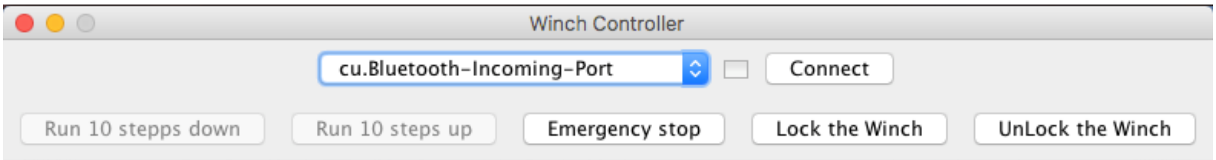


Test prototype ("simulator") Winch:

- Power supply
- Arduino
- Motor Shield
- Stop button
- 2 x stepper motor



GUI JAVA:



(Buttons on GUI):

- List of connections options
- Refresh
- Connection
- Run up
- Run down
- Emergency stop
- Lock the Winch
- Unlock the winch

Work to be done until next report

- Finishing up the attach and lock mechanism
- Print every part, as far as possible
- Assemble the winch components

Innføring i Mekatronikk
IP304814

Status Report

Simple Winch for SeaFarm

Date: 02.11.2017

Progress:

- Finished printing all major parts, and assembled together the winch.
- Started testing the functionality of the winch.
- Ordered all parts necessary for the projects, still awaiting some.
- All of the components to the main engine has arrived.
- GUI is ready ready.
- The payment for the slipring was delayed, but hopefully it will arrive soon.

Work to be done until next report

- Assemble the winch to finish up this part.
- Writing the report for the project.
- Assemble the locking and wire-leading mechanism.
- Make the system wireless and implement the system to the odroid.

Innføring i Mekatronikk
IP304814

Time Schedule

Simple Winch

NTNU
Norwegian University of Science and Technology

Date: 23.11.2017

Planned Time Schedule

Time Schedule											
Mechatronics Project - SeaFarm											
Simple Winch											
Week no.	38	39	40	41	42	43	44	45	46	47	48
Tasks											
Planning											
Budget	*										
Parts needed	*	*									
Measuring buoyancy	*	*									
Design	*	*									
Calculations	*	*									
Work flow plan	*										
Organize documents	*										
Mechanics											
Build Winch			*	*	*	*					
Build winch frame			*	*	*	*					
3D-printing parts		*	*								
Bulild stanby platform				*	*	*					
Optimize ROV rotation			*								
Attach ROV to platform						*	*				
Improve byouancy						*	*	*			
Automation											
Figure solutions for cables	*	*									
Configure program for the winch			*								
Connect winch program to existing						*	*	*	*		
Report											
Prepare report			*								
Write report								*	*	*	
Finish report										*	*
Misc.											
Finish Project											*

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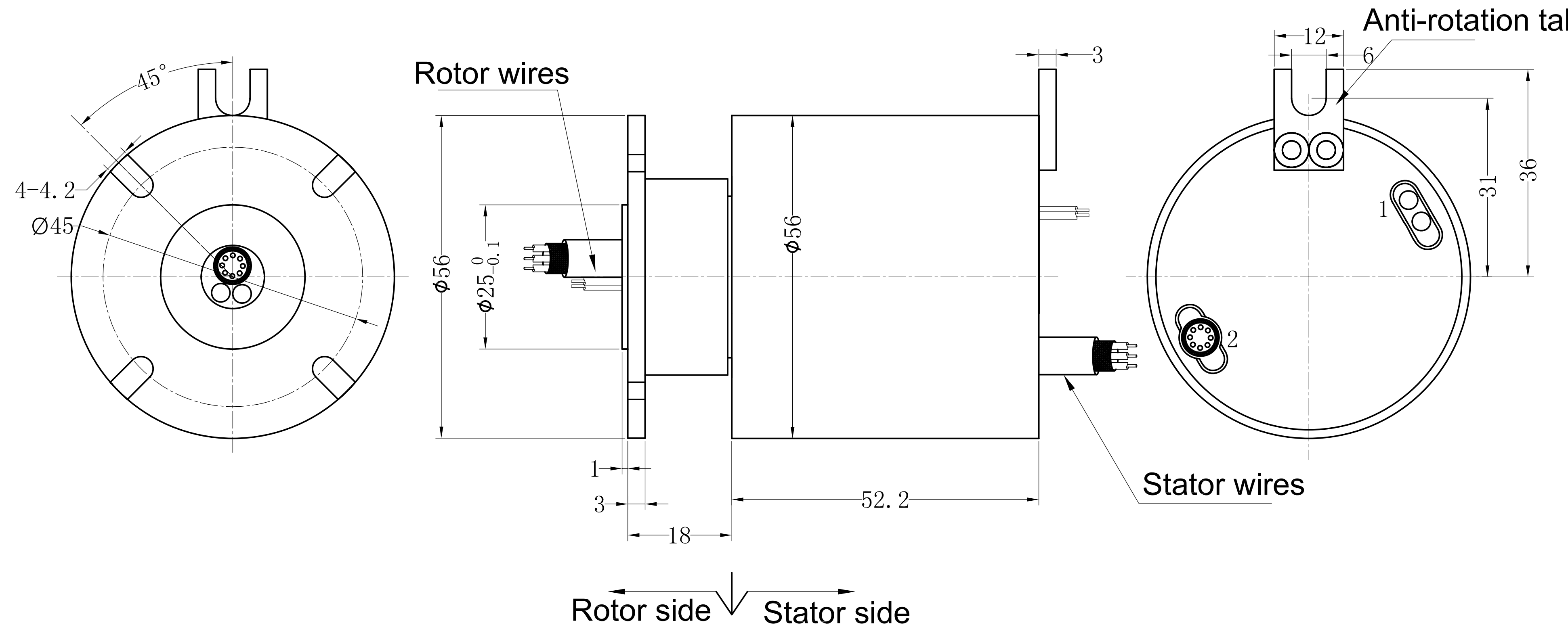
Actual Time Schedule

Time Schedule											
Mechatronics Project - SeaFarm											
Simple Winch											
Week no.	38	39	40	41	42	43	44	45	46	47	48
Tasks											
Planning											
Budget	*	*									
Parts needed	*	*									
Measuring buoyancy									*	*	
Design	*	*	*	*							
Calculations	*	*	*	*							
Work flow plan	*										
Organize documents	*										
Mechanics											
Build Winch				*	*	*	*	*	*		
Build winch frame											
3D-printing parts		*	*	*	*	*	*	*			
Bulild stanby platform				*	*	*					
Optimize ROVrotation			*								
Attach ROV to platform						*	*	*	*		
Improve byouancy						*	*	*			
Automation											
Figure solutions for cables	*	*	*	*							
Configure program for the winch			*	*	*	*					
Connect winch program to existing							*	*	*	*	
Report											
Prepare report			*								
Write report							*	*	*	*	
Finish report										*	*
Misc.											
Finish Project											*

MARK	ECN NO.	Modify	Approve	DATE



Electronic Specification

1	Rings	10	2	Current	Power module: 2rings, 25A/ring+1E
3	Voltage	0-440VDC/VAC			
4	Insulation Recistance	500MΩ@600VDC			
5	Electrical noise	Max.10mΩ;			
6	Dielectric strength	1000VAC@50Hz;			

Mechanical Specification

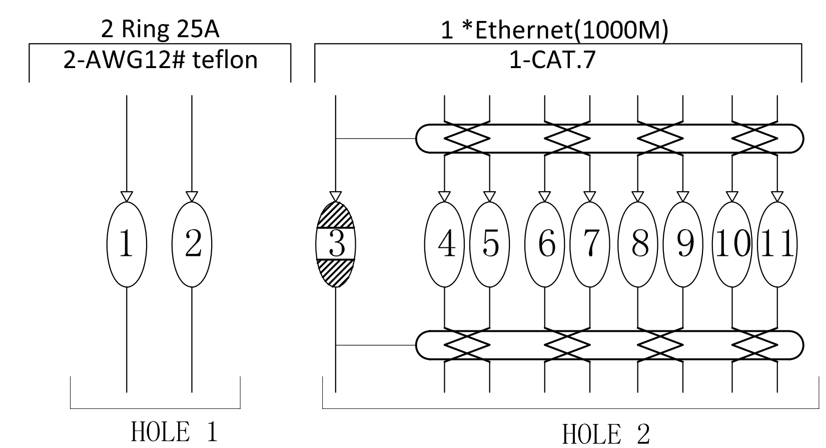
8	Speed	0~250RPM;	9	Torque	Max.0.5N.M;
10	Life	Typical: 120million revolutions, but strongly depends on your working conditions			

Environmental adaptability

11	Working temperature	-40℃~+80℃	12	Storage temperature	-45℃~+85℃
13	humidity	85±3%(30℃+5℃)	14	Vibration	10~30HZ Frequency,Double ampltude 0.8mm 30~200HZ Frequency, Acceieration 2g, two Circulation total 30min.
15	Rush	40g,11ms,Half sine wave, Vertical direction 3 times,Level 3times			
16	IP Class	IP51			

Material/Attachment

17	Contact Material	Gold-Gold	18	Housing material	ALL Alloy
19	Lead wire	Rotor:300mm(See wiring diagram) Stator:300mm(See wiring diagram)			



UNLESS OTHERWISE SPECIFIED 1.ALL DIMENSIONS ARE IN MM HES BREAK SHARP EDGES &DEBURR 2.MATERIAL&FINISH TO BE AS NOTED OR SUBSTITUTED WITH AN APPROVED AND TESTED EQUIVALENT	TOLERANCES (EXCEPT AS NOTED)	2 rings 25A Power+1E		
		MODEL	MZ056-P0225-1E(J663)	
FILLETS R.015 / FINISH 125	DECIMAL X±.1 XX±.03 XXX±.005	MOFLON	SIZE	A
			REV.	A/0
THIRD ANGLE PROJECTION	FRACTIONAL±1/16 ANGULAR±1°		SCALE	1:1
		DWG.NO LYG / DATE 2017/10/19	UNIT	mm

Locking mechanism

Simple winch

Date: 23.11.2017

Main solution

1. When the ROV is hoisted up, the user of the ROV pushes the "unlock" button.
2. The stepper motor is activated and drives the mechanism consisting of a timing belt and two gears. This is connected to a threaded rod installed on the side of the bearing on the moving "clamp".
3. When the rod is rotating, it moves the connected clamp to an unlocked position. It moves the distance of the certain amount of steps programmed to the stepper motor. The distance creates a sufficcient gap.
4. When the ROV is in the right position, the user pushes the "lock" button to drive the clamps togheter. The clamps will hold around the circular shape of the ROV. The ROV will also rest on the edge of the locking house.
5. When the ROV is hoisted down, the same procedure is activated.

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Science and Technology

Locking mechanism

Simple winch

Date: 23.11.2017

Optional main solution

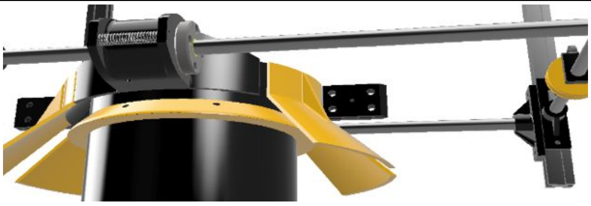
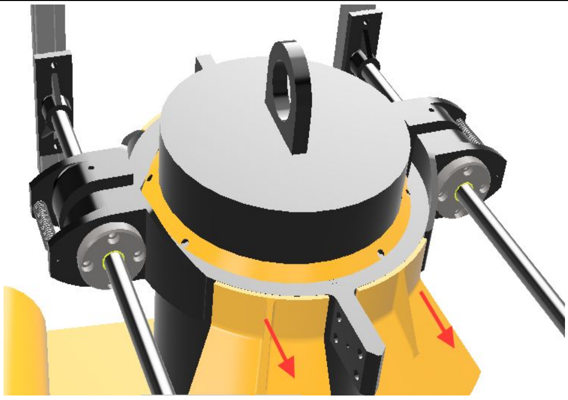
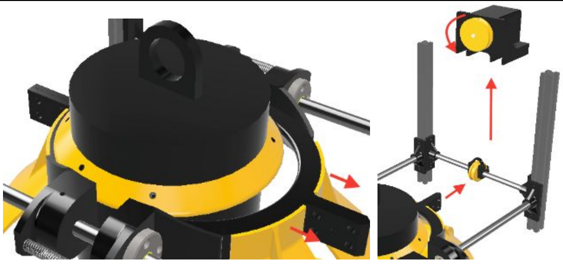
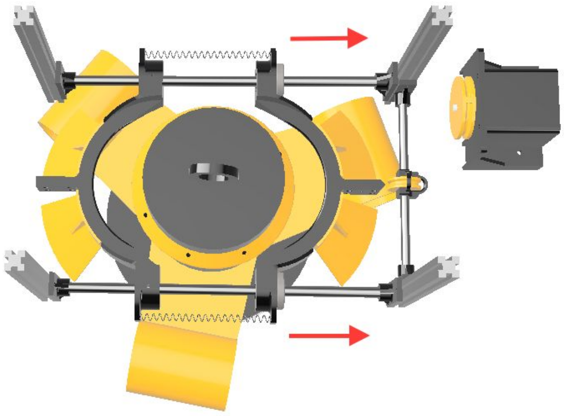
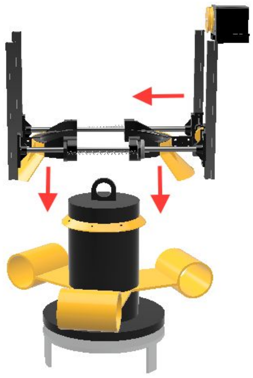
When hoisting the ROV, the ROV is lead into an aligned position in the locking house. The locking house consists of two parts, each shaped like a half circle bound together by one spring on each side. One half of the locking house is fixed onto the two shafts. The other half consists of two linear bearings	
The locking clamps of the ROV has a similar chamfered shape like the inside of the locking house, creating a track to glide on.	
When the ROV is hoisted further up, the locking part of the ROV will start to push the two separate parts of the locking house apart from each other. Nb: This scenario is if the ROV aligns naturally with the locking house. If not, a sufficient gap on the locking house will be created by using the stepper motor.	
When the locking clamps of the ROV is above the locking house, the clamps of the locking house slide back together again. The ROV now rests on the edges all around the locking house.	

Table 3 Self-aligning locking tool

To start the submerging of the ROV, the stepper motor is activated and the connecting movable part of the locking house is dragged out of position, unlocking the ROV from the locking house. This mechanism happens via two pulleys and one nylon string connecting the parts.	
The movable part of the locking house is dragged out of position before the ROV is totally unlocked. This creates a sufficient gap for the ROV to continue submerging thru the locking house NB: At the beginning of unlocking the ROV, the winch will slightly hoist the ROV up to unload the weight of the locking house, making it easier for the stepper motor to overcome the "negative" working forces.	
When the whole body of ROV has submerged the stepper motor can start to rewind the rotation of the pulley. The springs helps the locking house back to standby position. The tight nylon string connected to the stepper motor will slightly hold back the springs to keep the movement as smooth as possible.	
Now the locking house is back in standby.	

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Locking mechanism

Simple Winch

Date: 23.11.2017

Calculations optional main solution

Stepper motor

To unlock the locking house, the Nema 23 stepper motor has to overcome the forces in the extended springs. The critical force will appear when the springs are at maximum extension, when the locking house is totally unlocked and has created a sufficient gap.

Springs

Number of springs	2	-
Distance max extension	0,110	m
Constant factor	44,85	N/m
Force at full extension	9,9	N

Pulley block and motor

Radius of pulley block	0,025	m
Minimum demanding torque from motor	0,247	Nm
Safety factor	1,5	-
Torque motor	0,371	Nm

Note: This is only a quick estimate, therefore friction and drag forces are neglected.

Rotation of pulley

To lock and unlock the ROV, the pulley block has to rotate a certain amount to create a necessary gap. The size of the gap and the leaders will ensure to "catch" and "free" the ROV. If the ROV doesn't align naturally with the locking house, the gap will ensure to catch it and lock it.

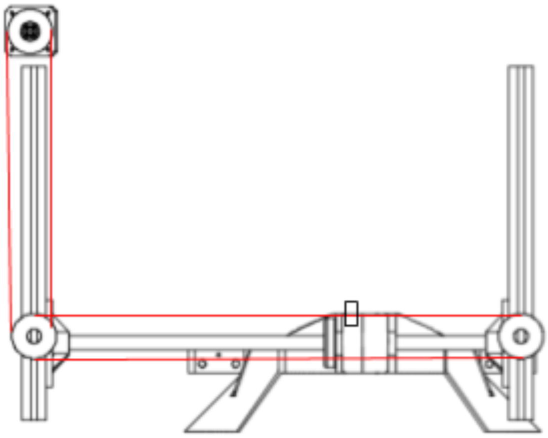
Maximal gap to lock/unlock ROV	110	mm
Diameter pulley block	25	mm
Circumference of pulley	78,5	mm
Rotation of stepper motor	11п/5 396	Radian Degrees

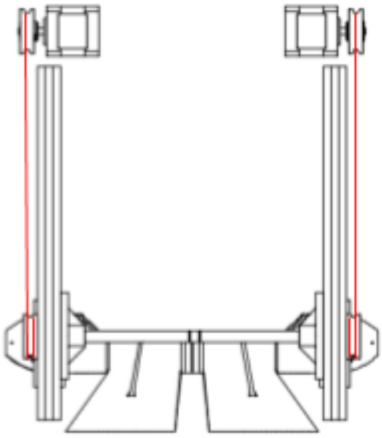
Locking mechanism

Simple Winch

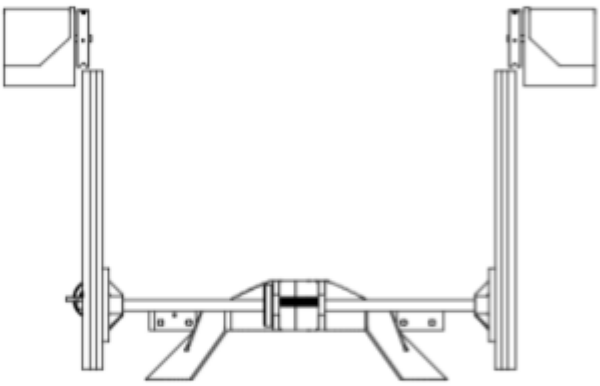
Date: 23.11.2017

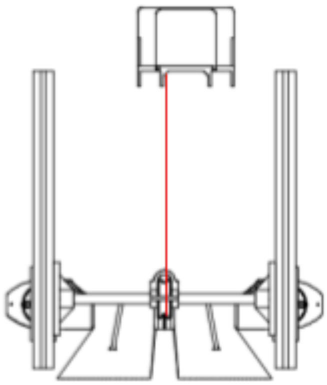
Optional solutions





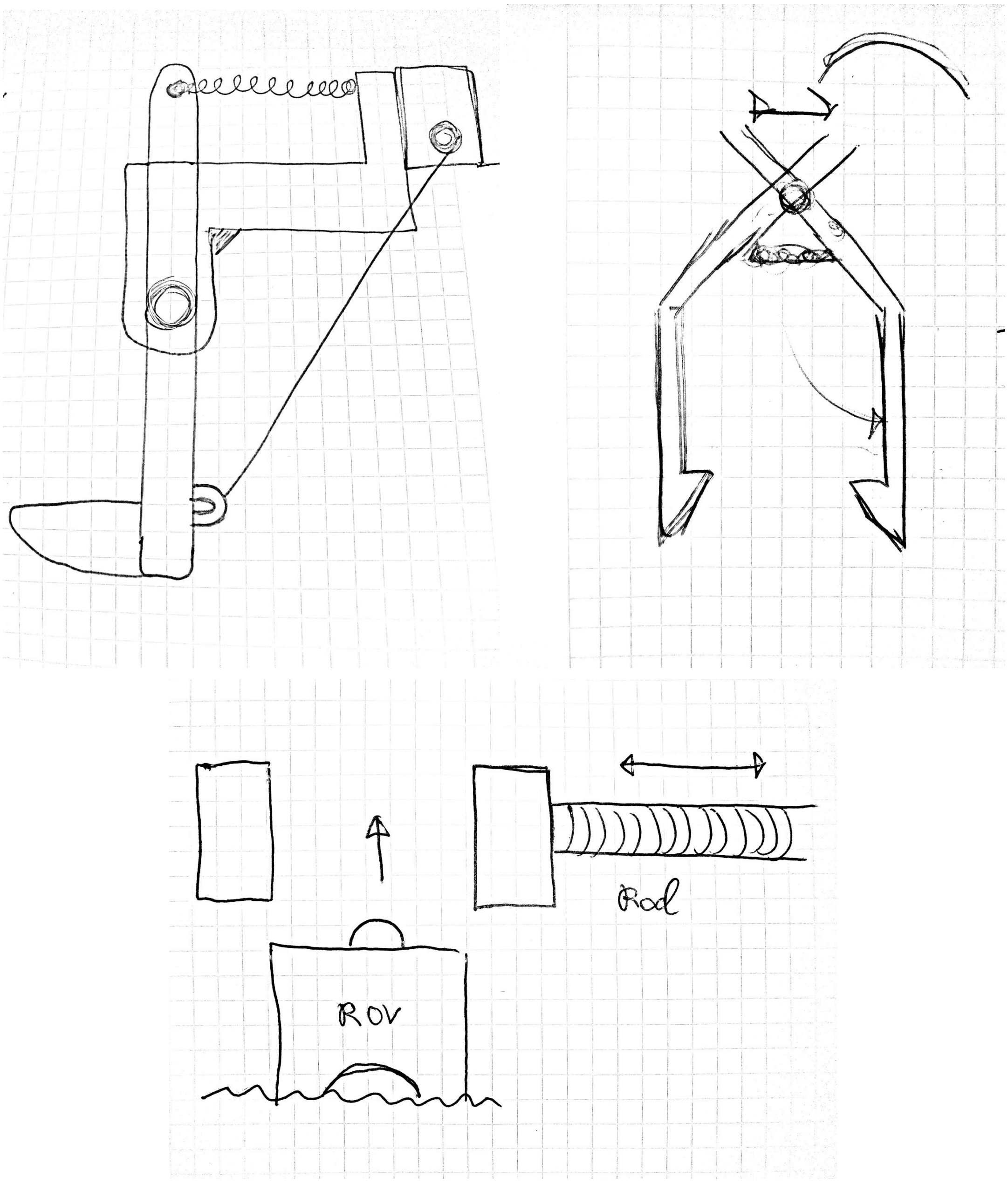
In this solution we have timing belts and several pulleys. The moveable clamp of the locking house is mounted on the belt between the center of two connected pulleys on each side. This allows the stepper motors to drive the clamp both forward and back.

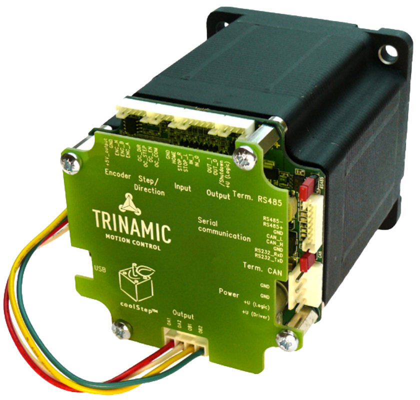




This solution is more similar to the one tested out. The main difference is that both of the clamps of the locking house is moveable, connected via 2 stepper motor. One for each clamp.

Optional solutions in early stage





PD86-1180

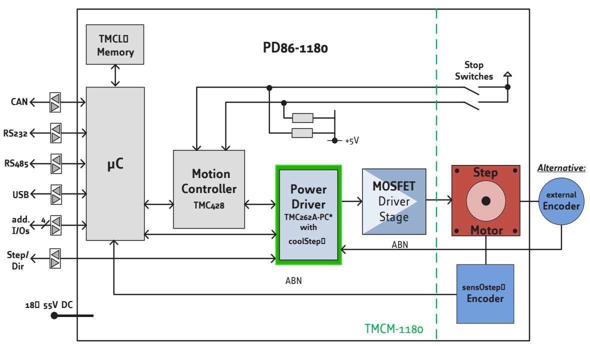
86mm / NEMA34 Stepper Motor with Controller / Driver, Encoder and Serial Interface Optional CANopen

INFO

The PANdrive PD86-1180 is a mechatronic solution including a 86mm flange motor, a controller board and a sensOstep™ encoder. It can be controlled via serial interface or operated in stand-alone mode. Power supply, external encoder, interface and multi purpose I/Os can be connected with JST connectors.

With the advanced stallGuard2™ feature the load of the motor can be detected with high resolution. The new outstanding coolStep™ technology for sensorless load dependent current control allows energy efficient motor operation.

The PD86-1180 comes with the PC based software development environment TMCL-IDE for the Trinamic Motion Control Language (TMCL™). Predefined high level TMCL™ commands guarantee a rapid development of motion control applications. Communication traffic is kept very low since all time critical operations, e.g. ramp calculation are performed onboard. CANopen firmware will be available optionally.



MAIN CHARACTERISTICS

ELECTRICAL DATA
- 24 to 48V DC (nom.) supply voltage

MOTOR DATA
- flange size 86mm/NEMA34
- holding torque 7.0 Nm

INTERFACE
- CAN, USB, RS232, RS485
- step&direction interface
- inputs for ref. & stop switches
- general purpose I/Os
- encoder interface (ABN)

FEATURES
- stallGuard2™ sensorless high resolution load detection
- coolStep™ sensorless load dependent current control
- up to 256 times microstepping
- microPlyer™ 16 to 256 times microstepping interpolation
- memory for 2048 TMCL commands
- motion profile calculation in hardware (RT)
- on the fly alteration of motion parameters (e.g. position, velocity, acceleration)

SOFTWARE
- stand-alone operation using TMCL™ or remote controlled operation
- PC-based application development software TMCL-IDE included
- optional CANopen firmware (CiA 302, 402)

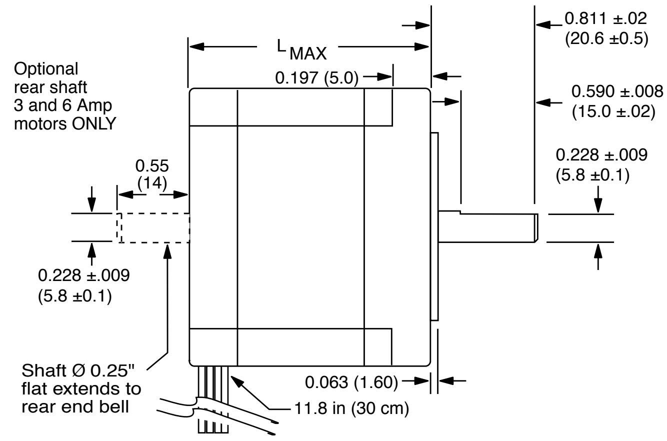
OTHER
- pluggable JST connectors
- RoHS compliant

ORDER CODE	DESCRIPTION
PD86-3-1180 (-option)	PANdrive 7.00 Nm, 118.5mm length with motor QSH8618-96-55-700
INTERFACE OPTIONS	
TMCL	with TMCL™ firmware
CANopen	with CANopen firmware (under development)

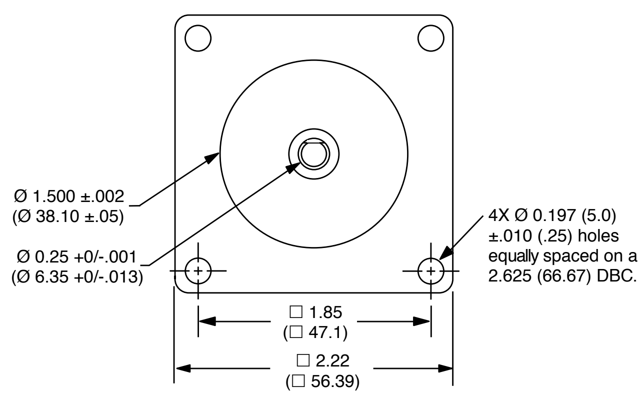
Quick Reference NEMA size 23 1.8° 2-phase stepper motor

Mechanical Specifications

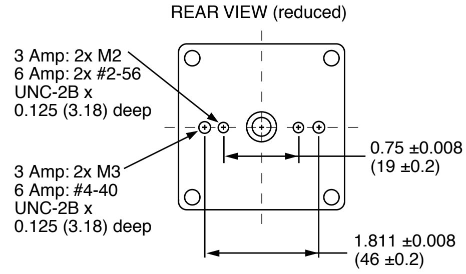
Dimensions in inches (mm)



FRONT VIEW



REAR VIEW (reduced)



Motor stack length inches (mm)	2.4 Amp motors	3.0 Amp motors	6.0 Amp motors
Single	1.77 (45)	1.77 (45)	1.75 (44.5)
Double	2.13 (54)	2.13 (54)	2.2 (56)
Triple	2.99 (76)	2.99 (76)	3.09 (78.5)

Notes and Warnings

Installation, configuration and maintenance must be carried out by qualified technicians only. You must have detailed information to be able to carry out this work.

- Unexpected dangers may be encountered when working with this product!
- Incorrect use may destroy this product and connected components!

For more information, go to www.imshome.com

Specifications

2.4 Amp motors		Single length	Double length	Triple length
Part number		**M-2218-2.4S** *(1)*	**M-2222-2.4S** *(1)*	**M-2231-2.4S** *(1)*
Holding torque	oz-in	90	144	239
	N-cm	64	102	169
Detent torque	oz-in	3.9	5.6	9.7
	N-cm	2.7	3.9	6.9
Rotor inertia	oz-in-sec^2	0.00255	0.00368	0.0065
	kg-cm^2	0.18	0.26	0.468
Weight	oz	16.9	21.2	35.3
	grams	480	600	1000
Phase current	amps	2.4	2.4	2.4
Phase resistance	ohms	0.95	1.2	1.5
Phase inductance	mH	2.4	4.0	5.4

(1) Only available with single shaft.

3.0 Amp motors		Single length	Double length	Triple length
Part number		**M-2218-3.0•** *(1)*	**M-2222-3.0•** *(1)*	**M-2231-3.0•** *(1)*
Holding torque	oz-in	90	144	239
	N-cm	64	102	169
Detent torque	oz-in	3.9	5.6	9.7
	N-cm	2.7	3.9	6.9
Rotor inertia	oz-in-sec^2	0.00255	0.00368	0.0065
	kg-cm^2	0.18	0.26	0.468
Weight	oz	16.9	21.2	35.3
	grams	480	600	1000
Phase current	amps	3.0	3.0	3.0
Phase resistance	ohms	0.65	0.85	0.95
Phase inductance	mH	1.5	2.6	3.36

(1) Indicate S for single-shaft or D for double-shaft. Example M-2218-3.0S

6.0 Amp motors		Single length	Double length	Triple length
Part number		**M-2218-6.0•** *(1)*	**M-2222-6.0•** *(1)*	**M-2231-6.0•** *(1)*
Holding torque	oz-in	100	150	257
	N-cm	71	106	181
Detent torque	oz-in	2.0	3.0	5.0
	N-cm	1.4	2.1	3.5
Rotor inertia	oz-in-sec^2	0.0017	0.00397	0.0068
	kg-cm^2	0.12	0.28	0.48
Weight	oz	16.6	24.7	35.3
	grams	470	700	1000
Phase current	amps	6.0	6.0	6.0
Phase resistance	ohms	0.16	0.19	0.23
Phase inductance	mH	0.47	0.73	1.04

(1) Indicate S for single-shaft or D for double-shaft. Example M-2218-6.0S

Wiring and Connections

Signals and wire colors	2.4 Amp motors	3.0 Amp motors	6.0 Amp motors
Phase A	Red	Red	Black
Phase /A	White/red	White/red	Orange
Phase B	Green	Green	Red
Phase /B	White/green	White/green	Yellow

Part Numbers

Example:	**M - 2 2 1 8 - 2 . 4 S**
Stepper motor frame size **M-22** = NEMA 23 (2.3"/57 mm)	**M - 2 2** 1 8 - 2 . 4 S
Motor length **18-** = single stack **22-** = double stack **31-** = triple stack	M - 2 2 **1 8 -** 2 . 4 S
Phase current **2.4** = 2.4 Amps *(1)* **3.0** = 3.0 Amps **6.0** = 6.0 Amps	M - 2 2 1 8 - **2 . 4** S
Shaft **S** = single, front shaft only **D** = double, front and rear shafts	M - 2 2 1 8 - 2 . 4 **S**
Optional optical encoder *(2)* **ES** = Single-end **ED** = Differential **Line count** 100, 200, 250, 400, 500 or 1000 *(3)*	M - 2 2 1 8 - 2 . 4 **E S 1 0 0**

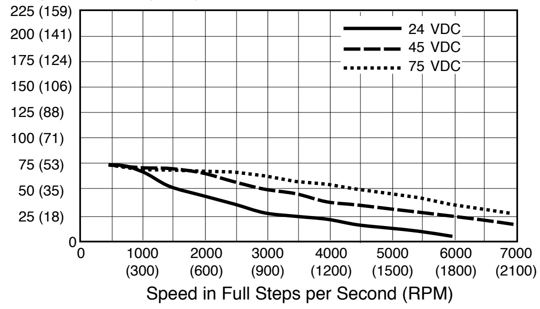
(1) Only available with single shaft.
(2) An encoder replaces the shaft designator in the part number.
(3) All encoders have an index mark, except the 1000 line count version.

Torque-speed Performance

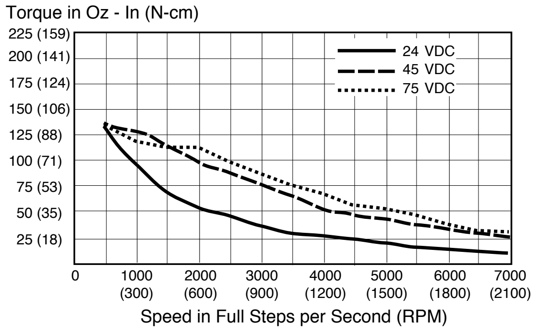
Measured at the rated phase current of the motor (RMS)

2.4 Amp motors

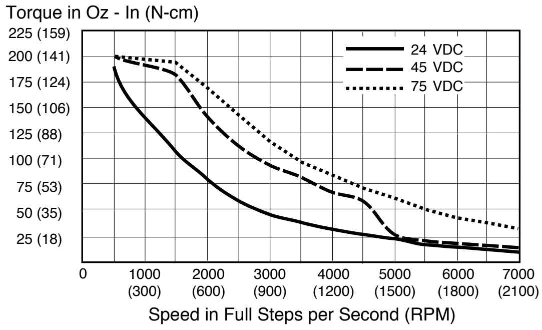
M-2218-2.4



M-2222-2.4

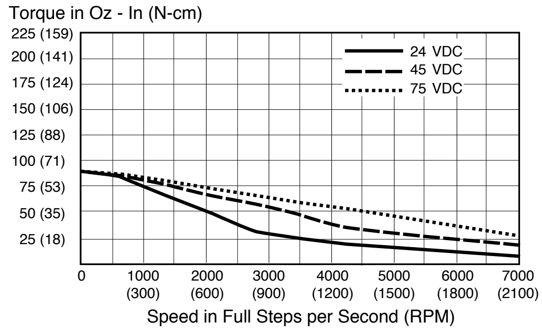


M-2231-2.4

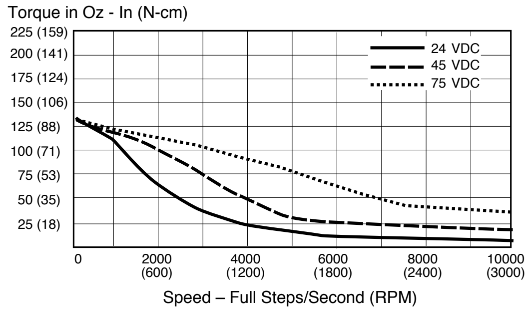


3.0 Amp motors

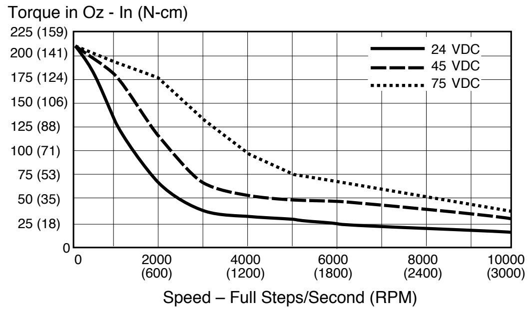
M-2218-3.0



M-2222-3.0

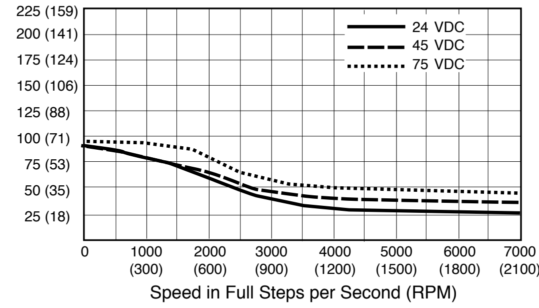


M-2231-3.0

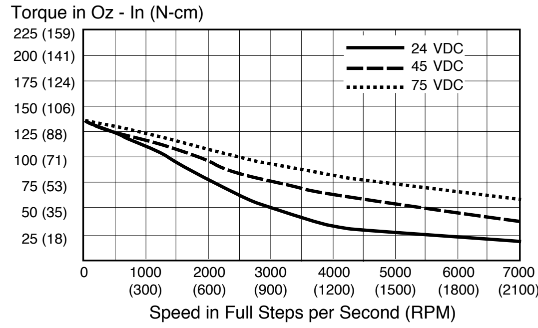


6.0 Amp motors

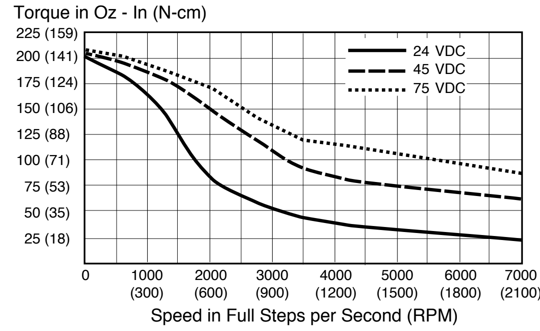
M-2218-6.0



M-2222-6.0

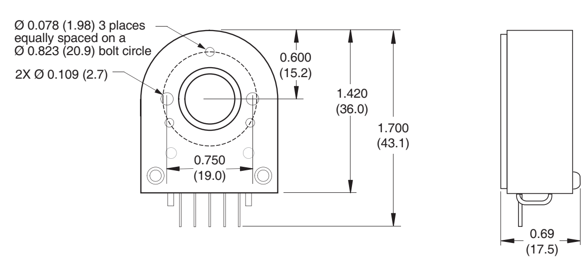


M-2231-6.0



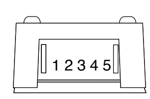
Optical Encoder Option

Dimensions in inches (mm)



Connectivity

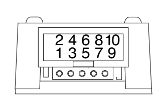
single-end encoder



wire		function
1	Brown	Ground
2	Violet	Index
3	Blue	Channel A
4	Orange	+5 VDC input
5	Yellow	Channel B

optional interface cable available: ES-CABLE-2

differential encoder

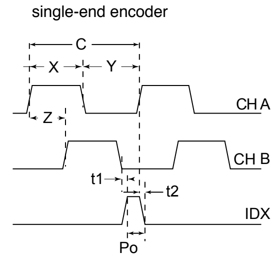


pin	function	pin	function
1	no connect	6	Channel A+
2	+5 VDC input	7	Channel B –
3	Ground	8	Channel B+
4	no connect	9	Index –
5	Channel A –	10	Index +

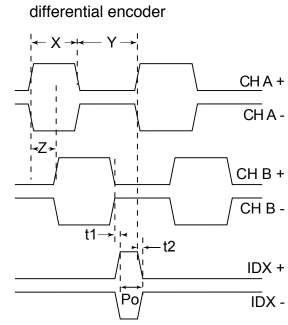
interface cable included

Timing

single-end encoder



differential encoder



Parameter	Symbol	Min	Typ	Max	Units
Cycle error			3	5.5	ºe
Symmetry		130	180	230	ºe
Quadrature		40	90	140	ºe
Index pulse width	Po	60	90	120	ºe
Index rise (after Ch A or B rise)	t1	-300	100	250	ns
Index fall (after Ch A or B fall)	t2	70	150	1000	ns

C One cycle: 360 electrical degrees (ºe).
X/Y Symmetry: the measure of the relationship between X and Y, nominally 180ºe.
Z Quadrature: the phase lead or lag between channels A and B, nominally 90ºe.
Po Index pulse width, nominally 90 ºe.
NOTE: Rotation is as viewed from the cover side of the encoder.

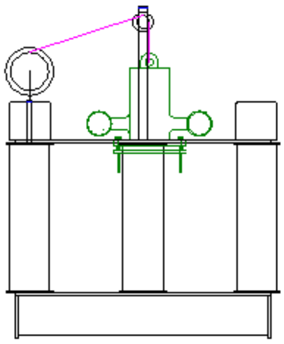
Winch Design

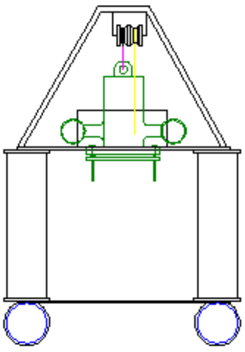
Suggestion no. 1

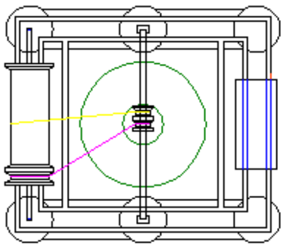
Date: 20.09.2017

Drawings of suggestion no.1, the design of winch for the SeaFarm. Roughly sketch

-







<u>Parts needed:</u>

Motor
Bearings
Drum (3D-print?)
Block (3D-print?)
Aluminium framing
Casing for the ROV to park in (plastic, like the buoyancy tubes?)
Steel wire

<u>Specifications</u>:
Motor: Stepper Motor, continuous running
Transmission: Planetary gear, ratio 1:10
Motor speed: 200 rpm
Required torque>2 Nm input/output
Lowing/Lifting speed: 0,2 m/s

Main lifting wire: Steel wire Ø3
One drum (cables and wire connected with heat shrink)
Drum diameter: Ø0,075 m

Pros:

ROV is placed above sea level on platform when not in use
Makes for a simpler solution to the lifting of the platform
Simple maintenance is able to perform when platform is in the water

Cons:

Platform is “heavier” to transport (more power usage)
Simple maintenance is not able to perform when the platform is in the water
Does require a few changes in the structure of the platform

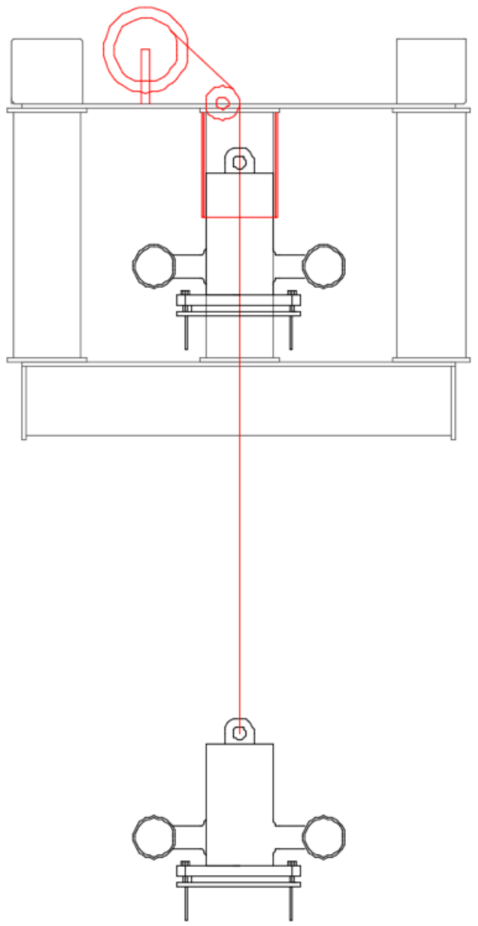
Innføring i Mekatronikk
IP304814

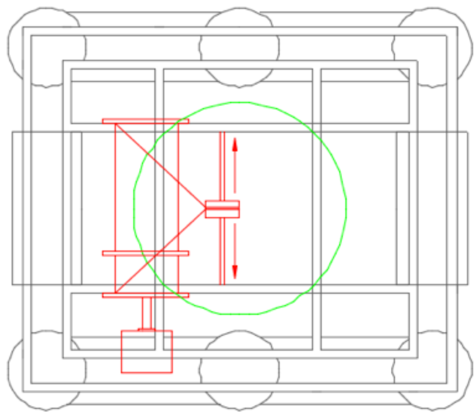
Winch Design

Suggestion no. 2

Date: 15.09.2017

Drawings of suggestion no.2, the design of winch for the SeaFarm. Roughly sketch





Cone to "park" the ROV in standby.
Better for stability of the SeaFarm.

<u>Specifications</u>:

Motor: Stepper Motor, continuous running
Transmission: Planetary gear, ratio 1:10
Required torque > 2 Nm output
Lowing/Lifting speed: 0,2 m/s

Main lifting wire: Steel wire Ø3
Double drum/ one drum(cables and wire connected with heat shrink)
Drum diameter: Ø0,075 m

Parts needed:

Motor
Bearings
Drum (3D-print?)
Block (3D-print?)
Aluminium framing
Casing for the ROV to park in (plastic, like the buoyancy tubes?)
Steel wire

Pros:

Compact Design
Less Weight
Makes for a simpler solution to the lifting of the platform
Makes for a simple parking solution of the ROV
Doesn’t require changes on the platform structure

Cons:

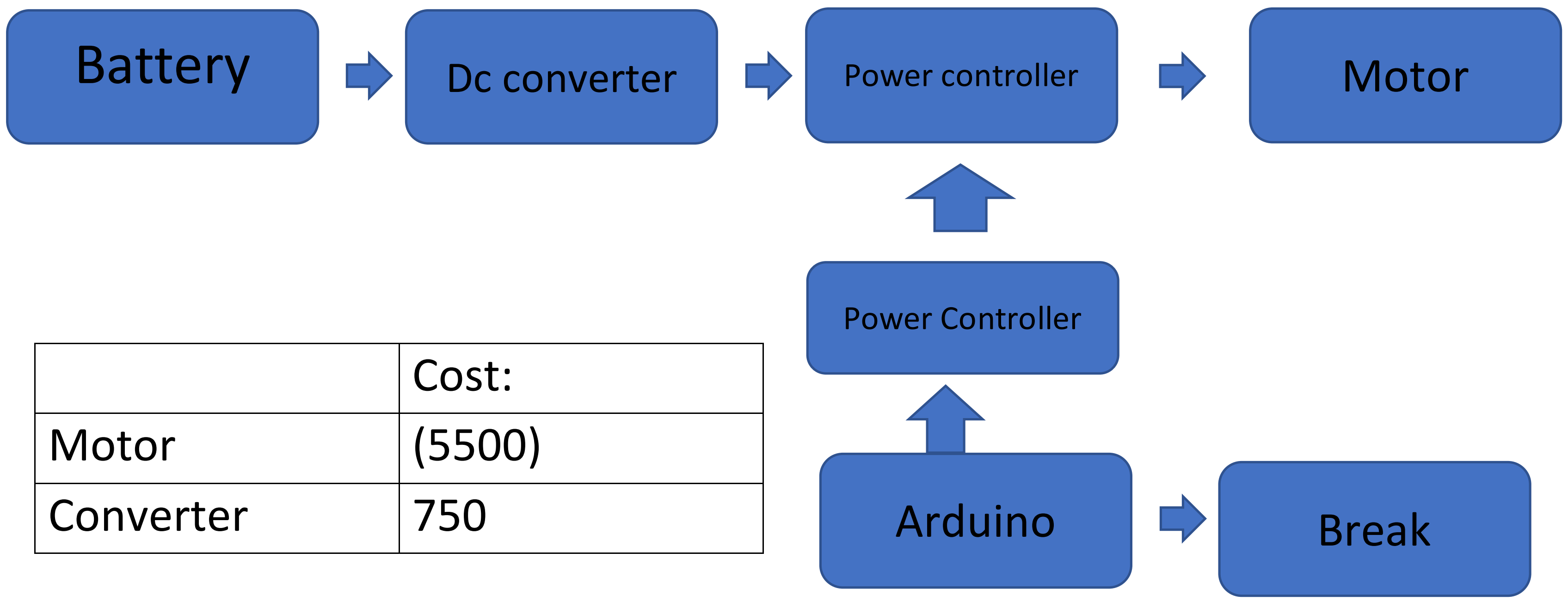
The ROV is exposed to water at all time when the platform is in use
Platform is “heavier” to transport (more power usage)
Simple maintenance is not able to perform when the platform is in the water

Stepper Motor

Pros	Cons
we have it at school	expensive
precision	Over Kill.(precision, torque)
Encoder	
more than enough torque	
7 Nm	

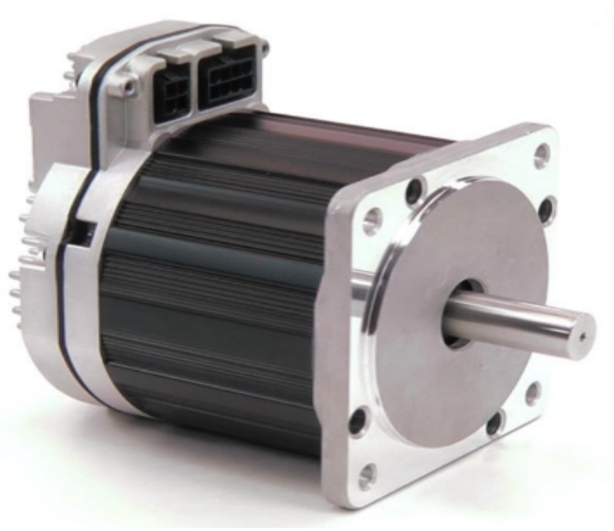
Motor Spec:
18….55V
5.5 A
Communication: -CAN -CANOPEN -RS232 (Perfect for Arduino) -Rs422

DC/DC converter Spec:
12V -> (15-24)V
(6 - 8,5)A
150W



	Cost:
Motor	(5500)
Converter	750

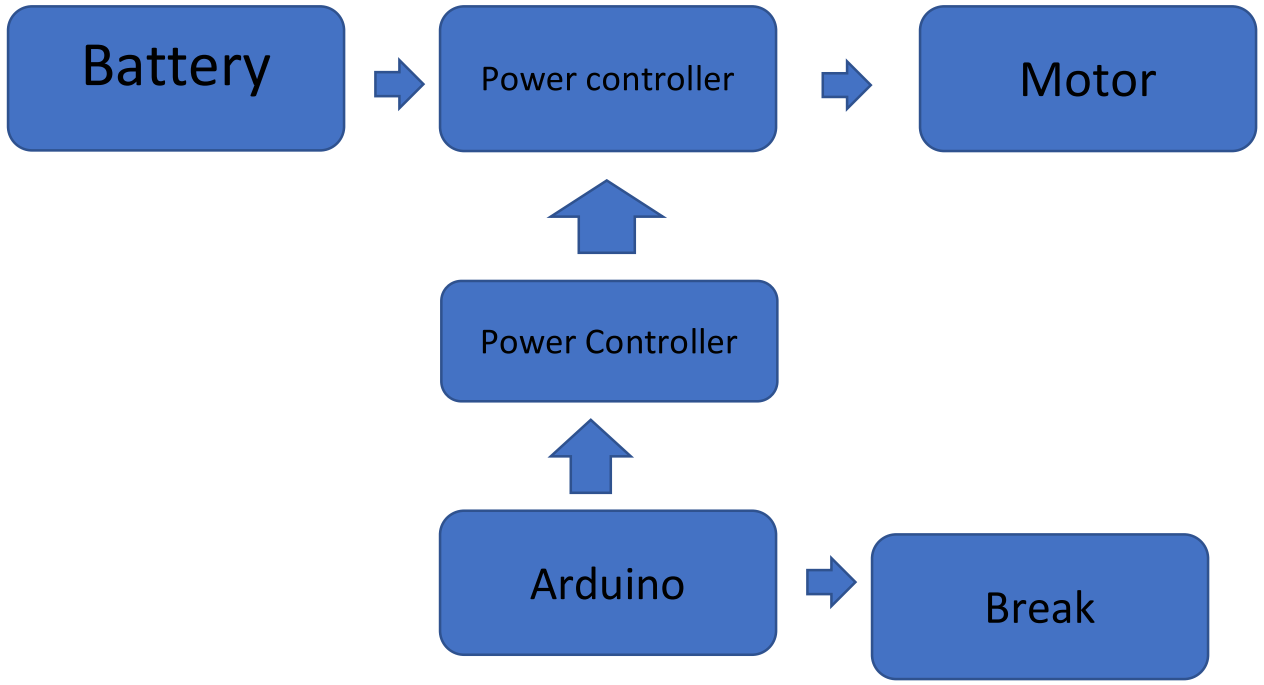
Servo motor



Pros	Cons
Easy to controll	expensive
Arduino Compatible	
Harder to control speed	Shipping 3 weeks
Torque 2 Nm	

Motor Spec:
12V
Comunication : -Polulu power controller -other controller.

	Cost:
Motor	4000 +-pr pice

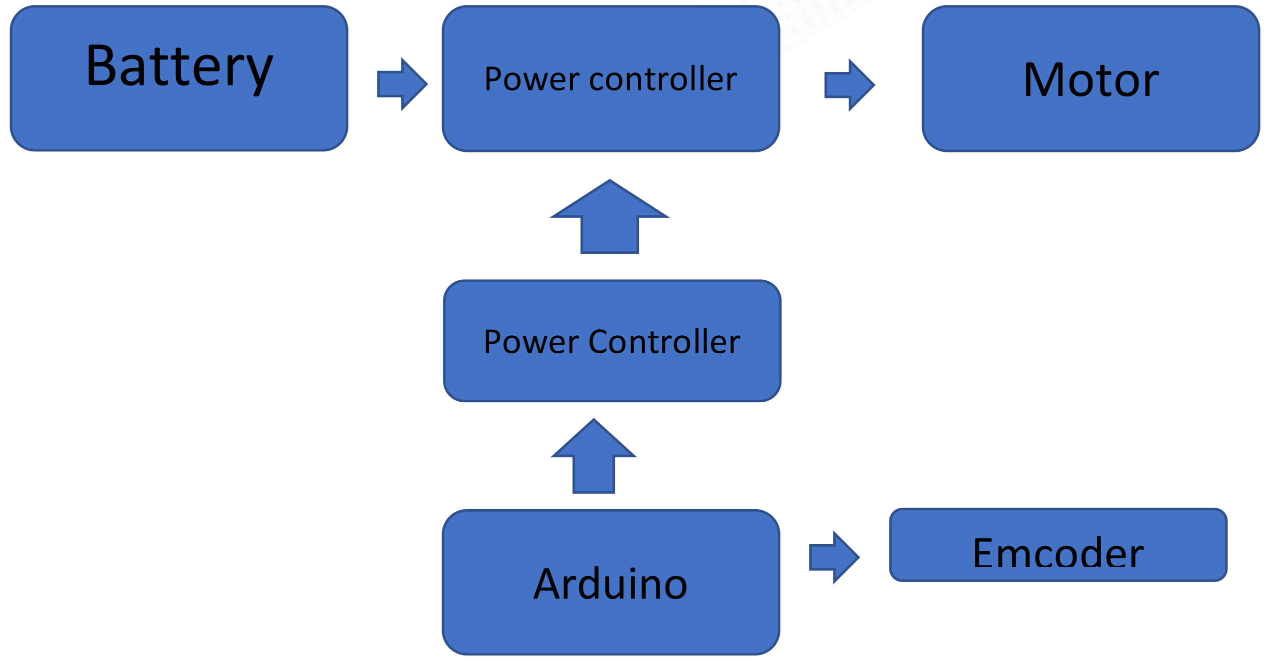


Wiper Motor

Pros	Cons
Strong	Slow
Cheap	No encoder
do not need brakes	No controller

Motor Spec:
12V
Comunication : -Polulu power controller -other controller.

	Cost:
Motor	1000+-500



Stepper motor Cheap

Pros	Cons
Cheap	Need 2 or 3
Arduino Compatible	No encoder
Shipping 1-2 week	Torque 1 Nm

Motor Spec:
12V
Comunication : -Polulu power controller -other controller.

	Cost:
Motor	300 400 pr pice