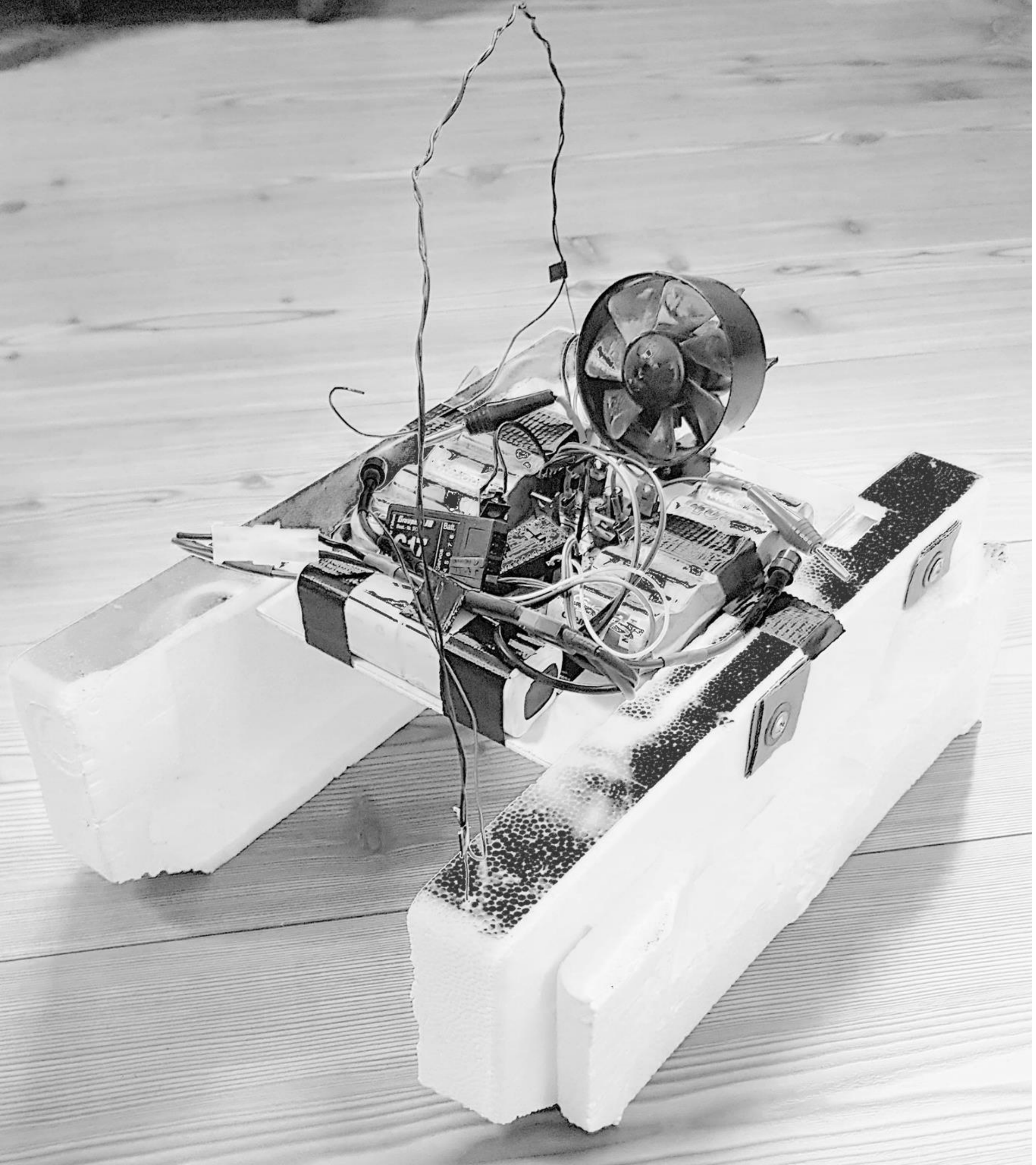

Remote controlled fan boat

Design & documentation
by Timo Benzel
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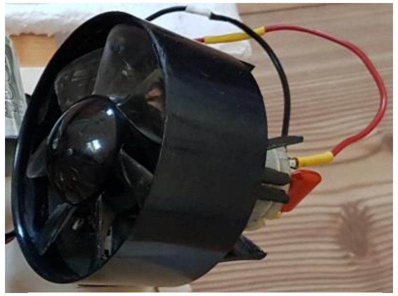
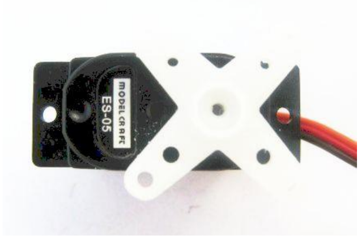
Project goal

- Design a remote controlled (RC) boat using electronic trash such as:
    - an old hair dryer fan
    - a servo motor to rotate the fan for steering
    - two old 12V batteries
    - two boards of styrofoam
    - a 35MHz RC-sender and receiver
      from an old model airplane



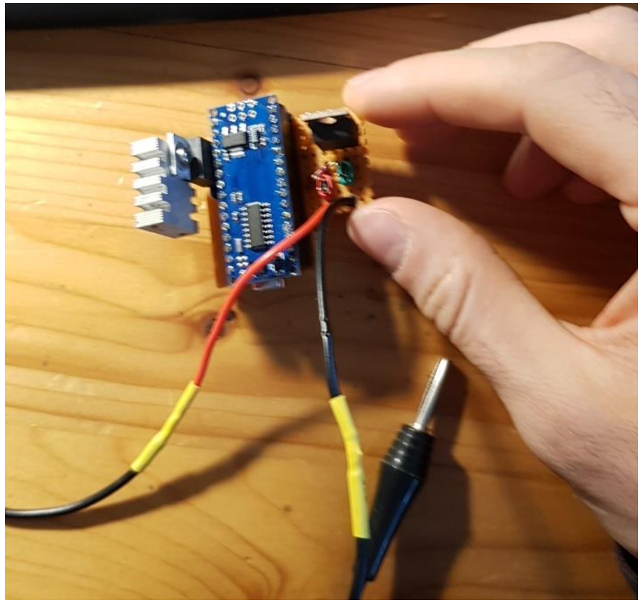


Requirements

- the boat shall be built out of used parts
  or already available parts (it is basically a trash boat)
- the boat has to always stay afloat for all maneuvers
- the boat has to be steerable within a range of at least 50m
- the boats thrust shall be controllable via remote control
- the boat shall not disintegrate itself
- the boat shall be made as fast as possible with the available parts

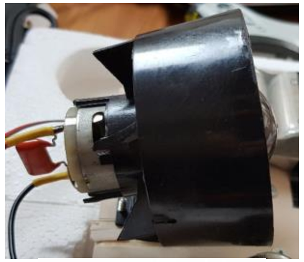
Version 1 – Goal

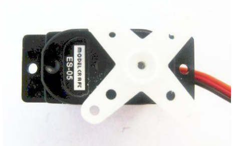
- Use a primitive setup for the proof-of-concept
  - Use an emitter circuit to control the power to the motor with PWM
  - 5V linear voltage regulator to power an Arduino Nano and the servo motor
  - screw the fan directly on the servo‘s plastic mounting cross (you will find a way ;))

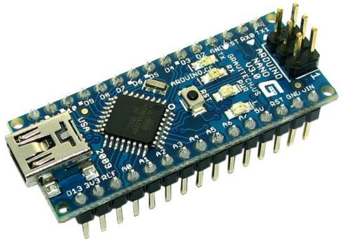


Version 1 – Parts used

- old hair dryer fan
- a servo motor to rotate the fan for steering
- two old 12V batteries
- two boards of styrofoam
- a 35MHz RC-sender and receiver
  from an old model airplane
- an Arduino Nano
- 5V linear voltage regulator
- Power MOSFET with 5V Vds threshold





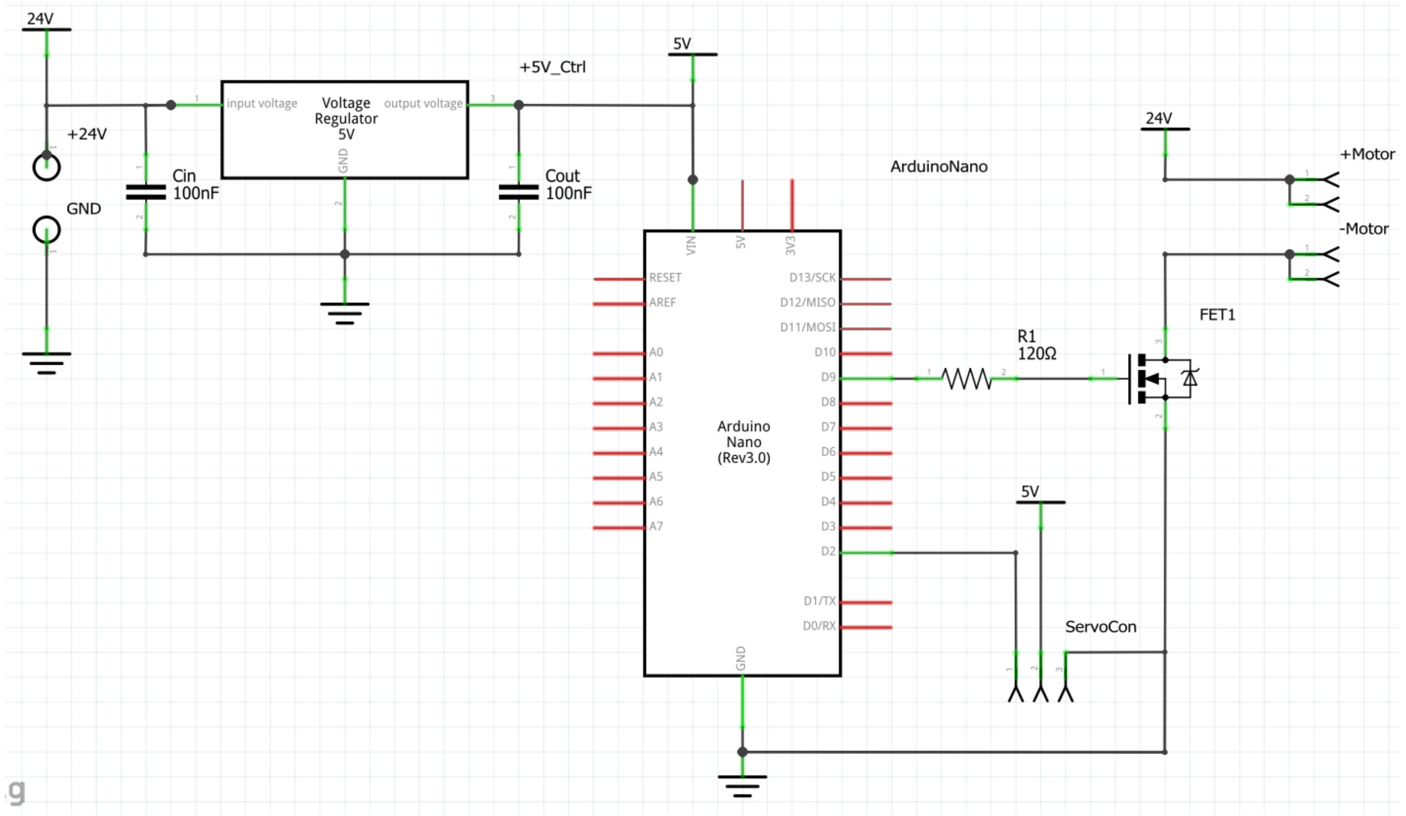


Version 1 – Build-up documentation

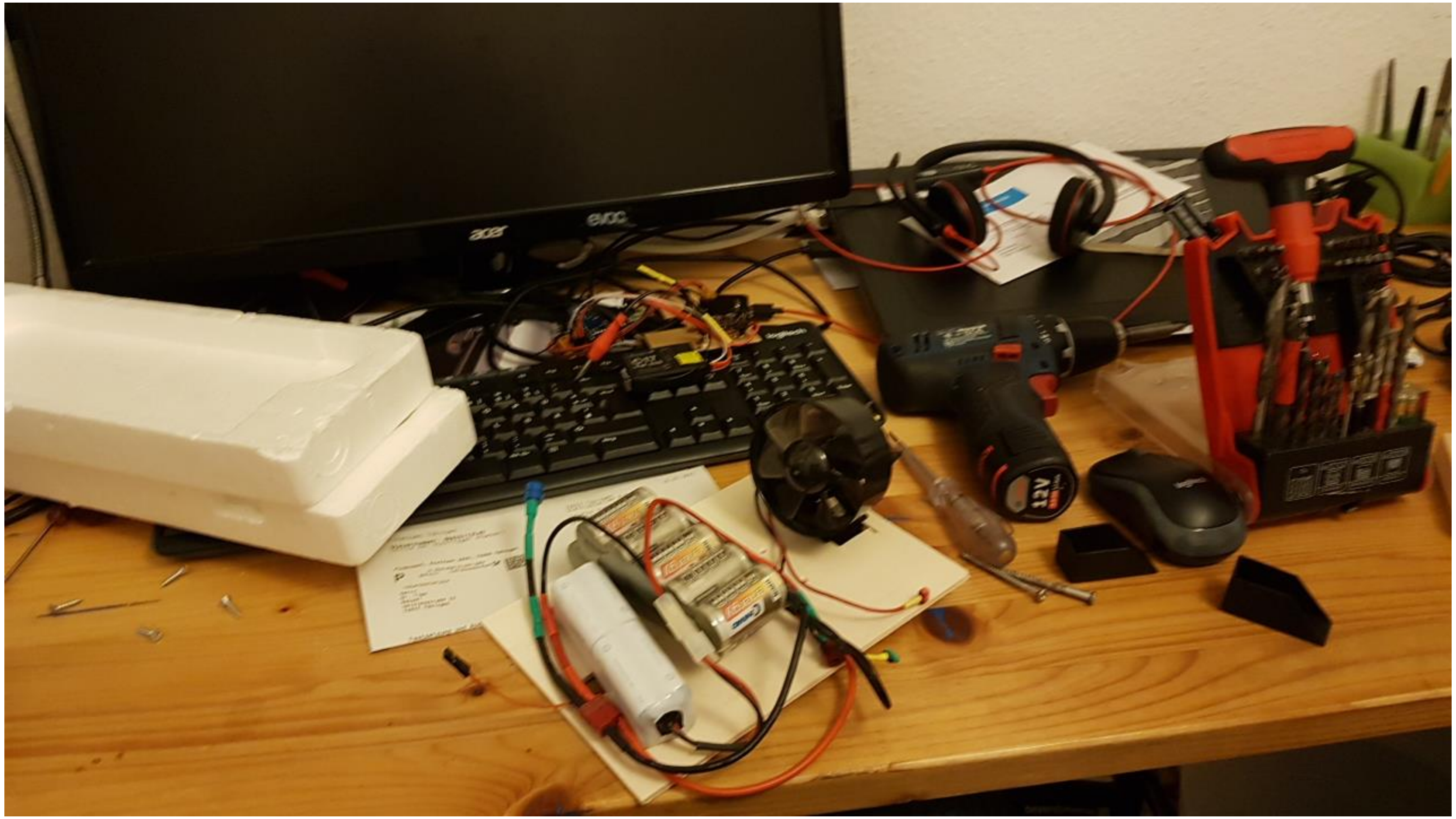
1. Start by cutting a hole in a small piece of wood/plywood on which the servo motor can be mounted
2. mount fan directly on servo using plastic screws from old eletronic devices
3. Mount the servo with the fan on top into hole

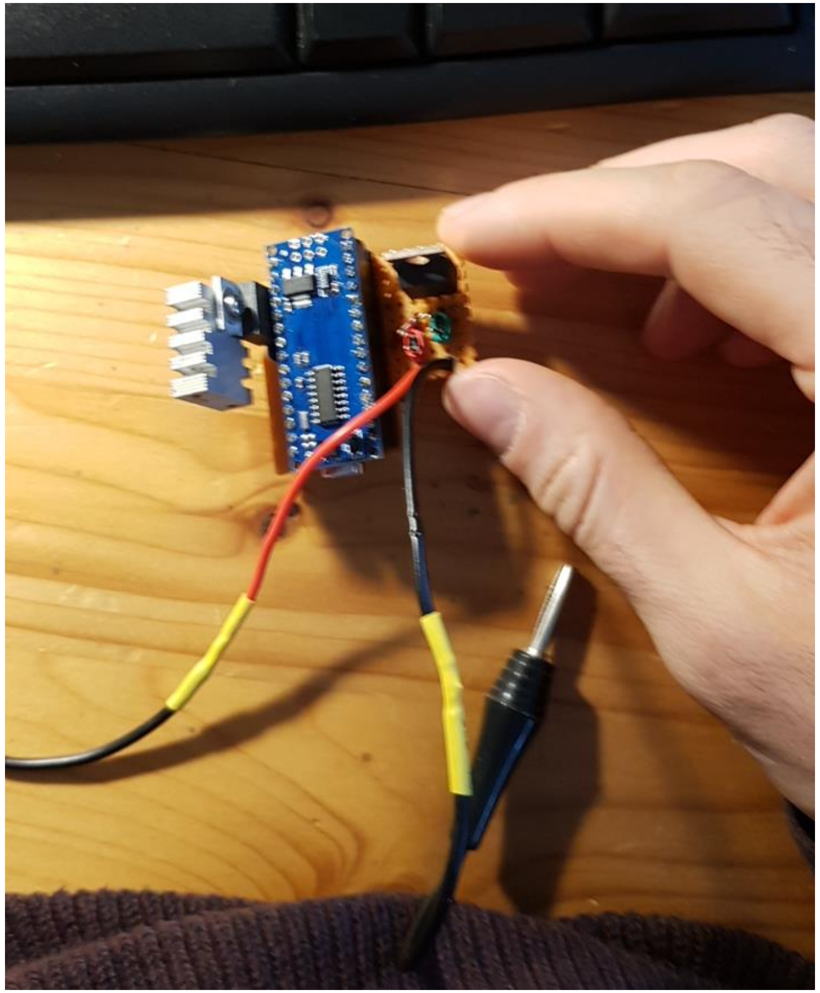
Version 1 – Build-up documentation

4. Connect two old 12V batteries in series in order for the output voltage to be high enough to generate enough fan speed (if you have different batteries just try out how many you need in order to get the voltage high enough for the fan to get up to speed)
5. Get a small piece of perfboard and put the components on there according to the schematic



Version 1 – Build-up documentation

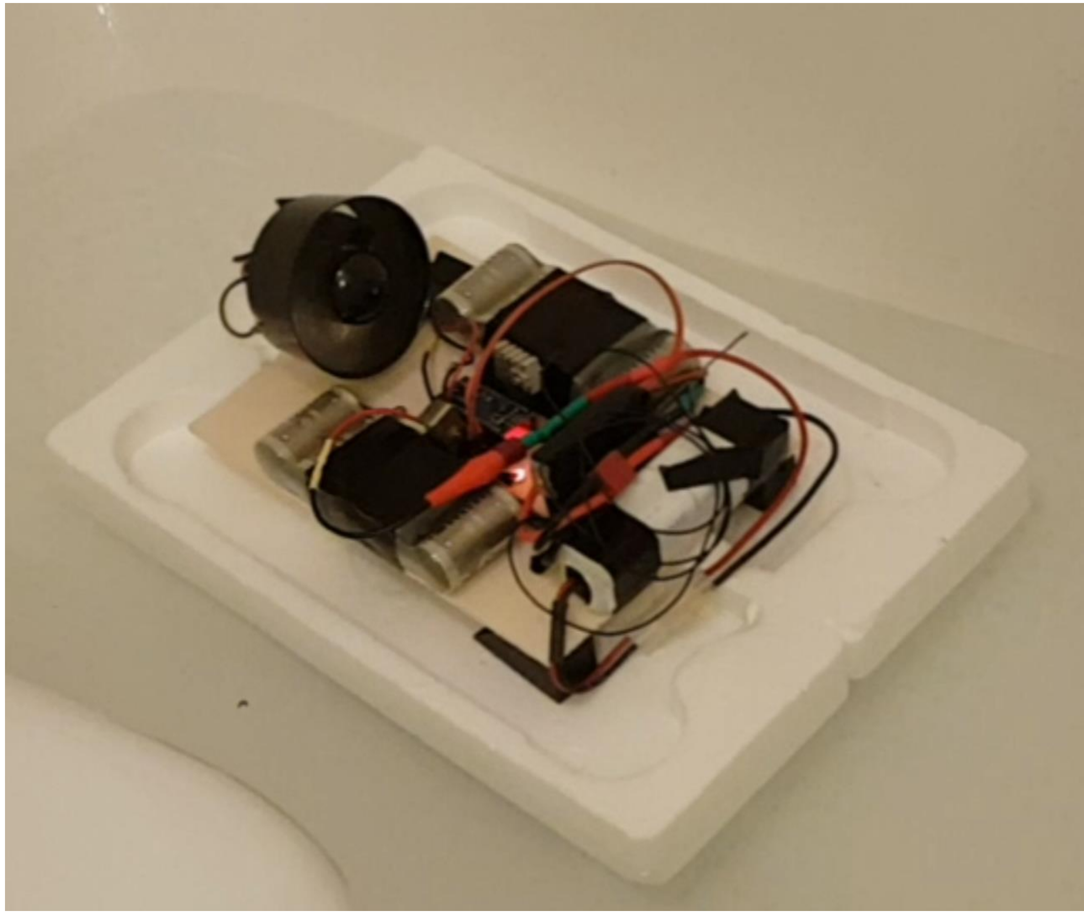




Version 1 – Build-up documentation

6. When you connect the plywood board to the styrofoam blocks always make sure you are using a clamping mechanism with tapping screws or use general purpose glue
   I clamped the two styrofoam pieces together with two sticks of wood through which i put wood screws

Careful: Test if your glue is corrosive to the styrofoam (e.g. superglue usually eat right thorugh styrofoam)



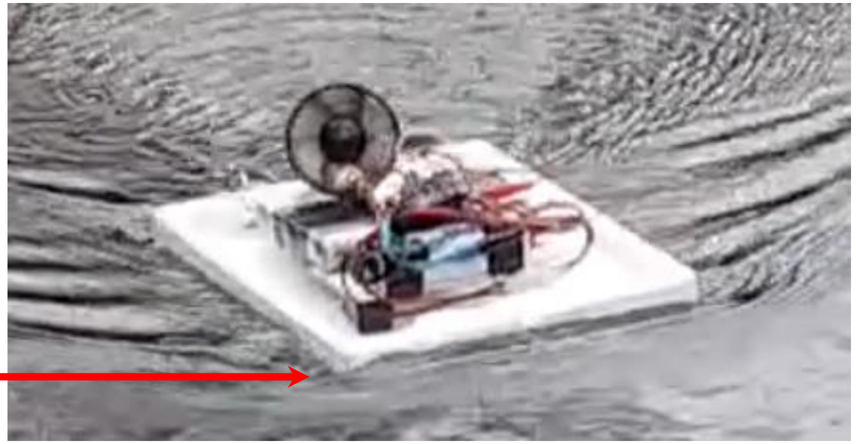
Version 1 taking a test swim in the bath tub

Version 1 – Validation

- The boat stays afloat → requirement fullfilled
- Boat is steerable and thrust controllable
- The boat is built out of old/used parts

Version 1 – Validation

- the boats crosssection was quite large and non-hydrodynamically shaped, so the bow wave was especially prominent

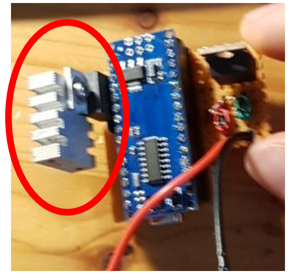


which caused

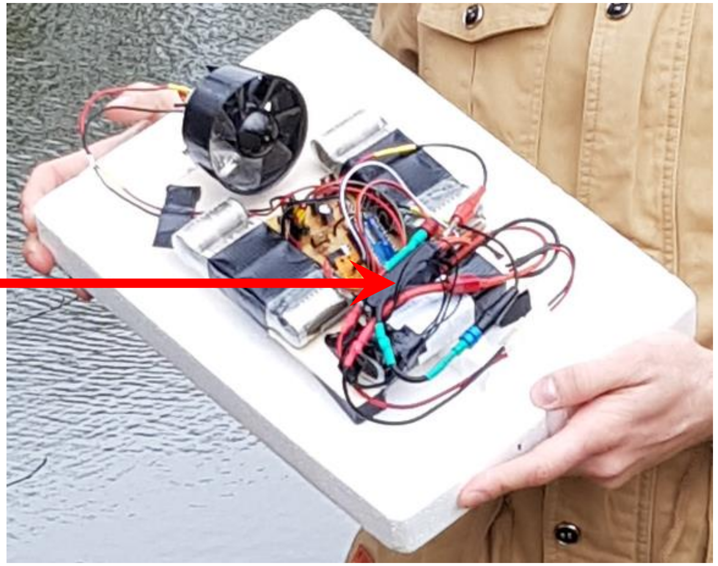
- increased drag
- water spilling into the cavity of the styrofoam blocks underneath the electronics (not too bad, but not ok)
- smaller max. velocity (ironically especially when thrust is high)

Version 1 – Validation

- The 5V linear voltage regulator reached >60°C even with a huge heat sink, especially when the servo was used a lot
  This temperature was considered to be too high

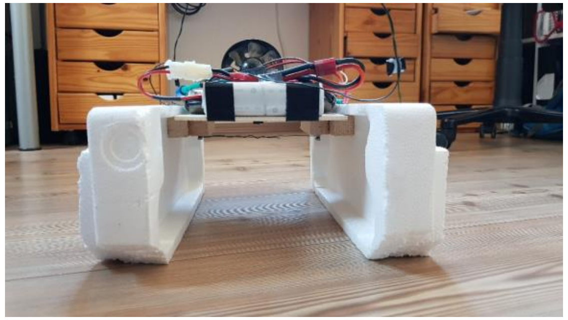


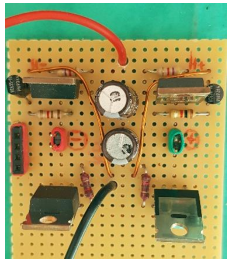
- In version 1 the antenna was wound up into a ring
  which decreased the range of good reception to only about 10m; beyond this range the controls would start acting up



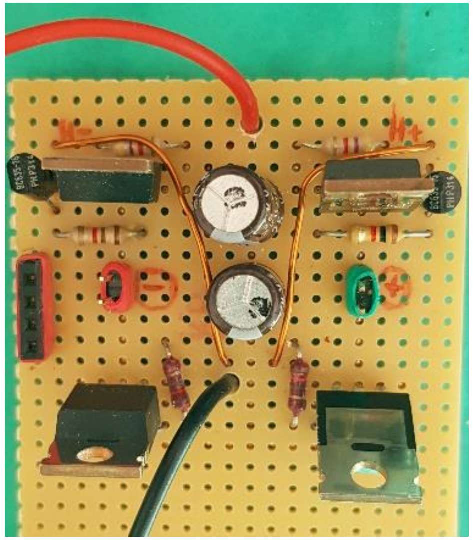
Version 2 – Goals

- This version needs to have the ability to generate reverse thrust by
  - using a full bridge power stage design
  - Sensing another channel from the receiver telling the arduino to control the powerstage in forward or in reverse
- Improvements on the previous design:
  - less drag due to smaller crosssection due to the katamaran design
  - instead of the use a full-bridge inverter design to create the possiblity of inverting the motor voltages and thus the capability to reverse thrust
  - replace the linear voltage regulator with a DC-DC step-down converter to generate the 5V with fewer losses and thus smaller temperatures

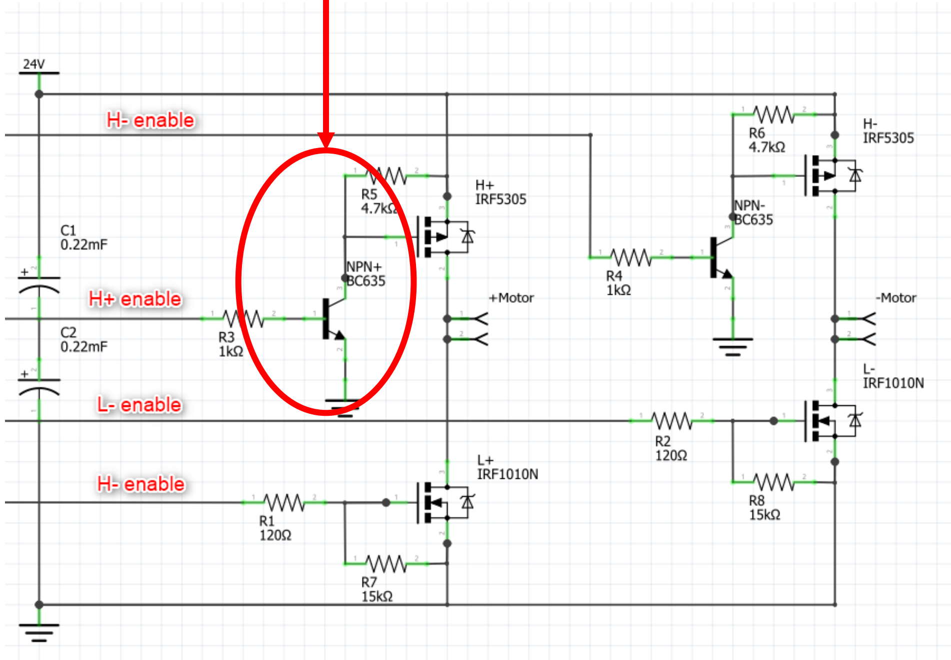




Version 2 – Build-up documentation

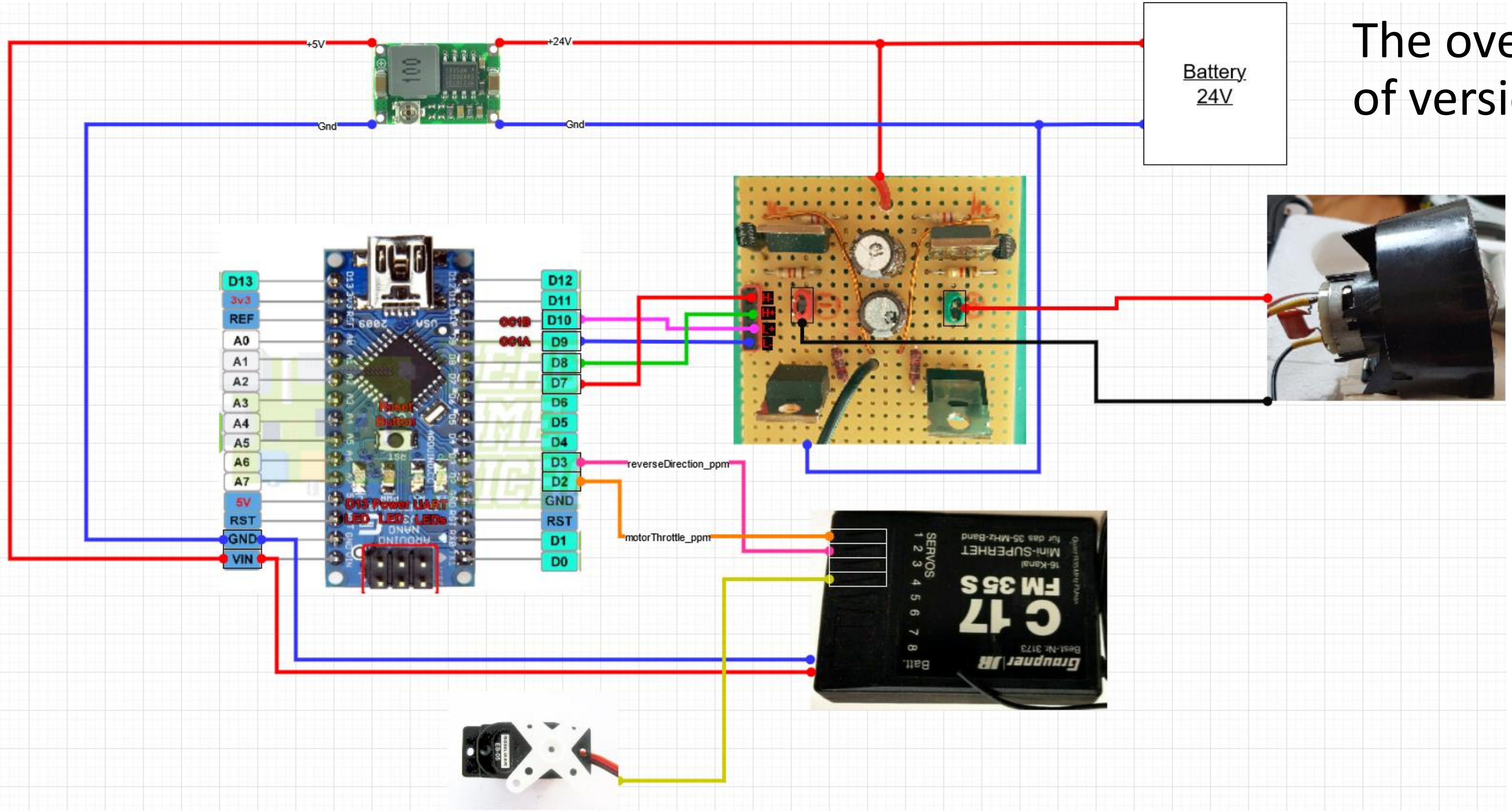


- The new full-bridge powerstage consists of 4 MOSFETs
- The highside (H+/H-) MOSFETs are used as switches via a level shifter with an NPN transistor
  (see also: http://electronics-diy.com/electronic_schematic.php?id=1012)
- The lowside MOSFETs are controlled directly with a PWM signal to control the motor power input
- for power control the lowsides are used because the lowside FETs are n-channel MOSFETs which switch much faster than the p-channel highside MOSFETs
  (probably due to my poor circuit design :D)



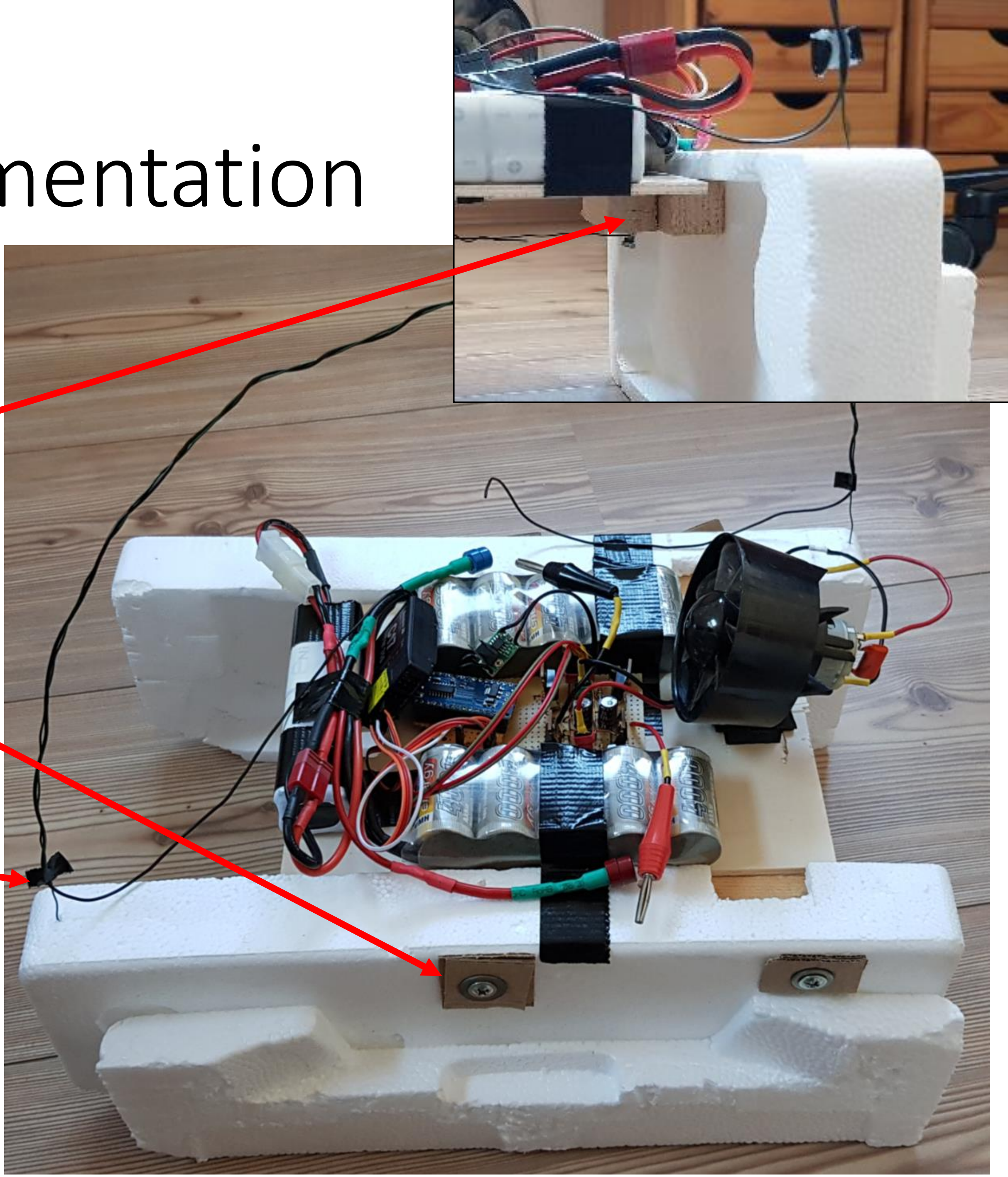
Version 2 – Build-up documentation

The overall wiring of version 2



Version 2 – Build-up documentation

- The plywood board was screwed onto two wooden bars, one on each side
- The wooden bars would be pushed against the styrofoam with screws supported by washers and cardboard on the ofter side of the foam block
- The antenna would be would around a thick wire fixed to the styrofoam to maximize ist straight length to increase reception

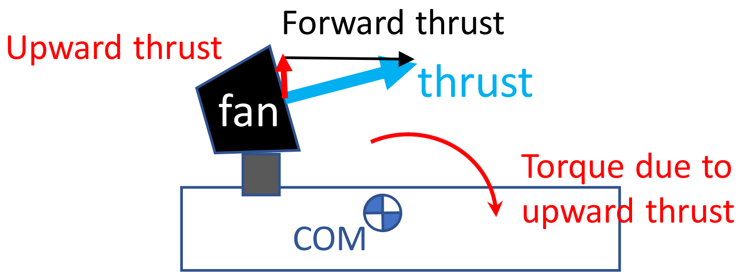


Version 2 – Build-up documentation

- Usually these hair dryer fans work with AC voltage, which is why they have a rectifier attached between the power supply and the connectors to the brushes
  → now that we want to apply negative voltages to the motor, we need to remove the rectifier
  But: leave the intermediate circuit capcitor on there. It makes sure, that the high voltage sparks from the brushes does not affect your power electronics too much

Version 2 – Validation

- The range is much larger now > 20m → the straightened antenna design works well
- the fan was facing upward which caused a torque pushing down the bow of the boat which still caused:
  - increased drag
  - smaller max. velocity (ironically especially
  - less thrust being directed forward but downward

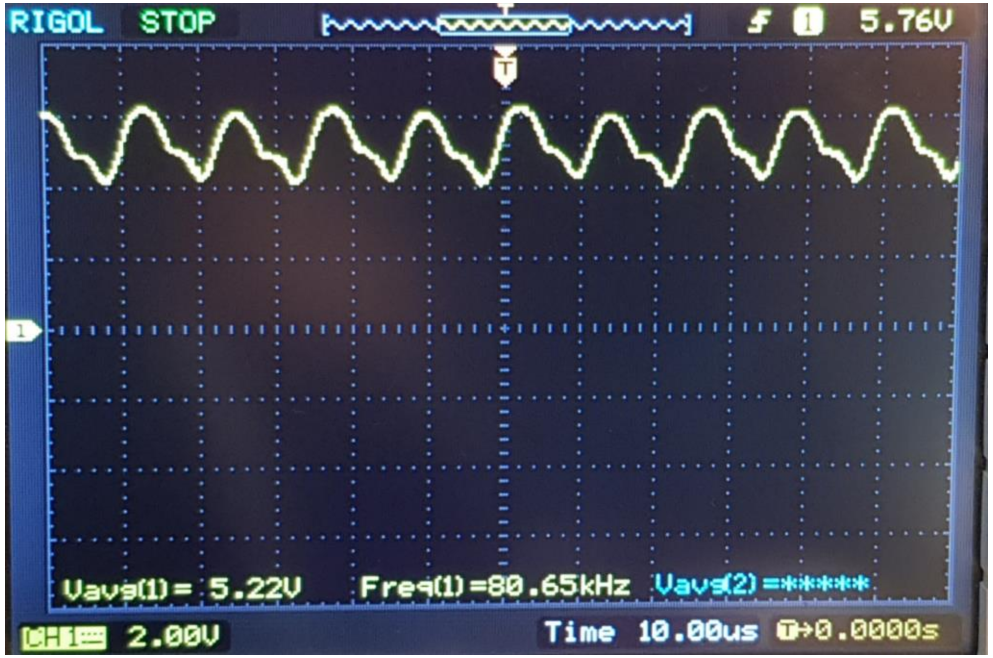


Version 2 – Validation

- The RC receiver got damaged after the validation at home (reason unknown)
  - Symptom: All control signals behaved erratic
  - Root cause lies in the receiver
  - Origin might be the voltage harmonics in the DC-DC converter, that might have damaged the receiver
    → 35 MHz RC system needs to be replaced
    with 2,4 Ghz system (more robust when it comes to disturbances)

Version 2 – Validation

- Power supply output filter needs to be installed
  because the 5V voltage output of the DC-DC converter ripples dramatically with a 2Vpp value at 80 kHz
  this behavior might damage other components as well



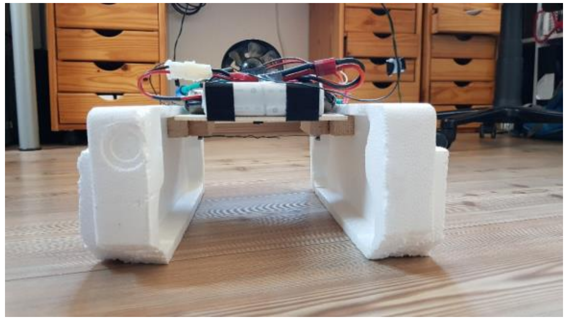
Version 2 – Validation

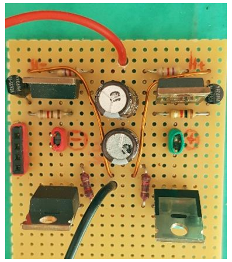
- There are still issues with the forward-backward direction

  - When the sender is put into „backward“ and then the receiver is turned on the motor does not react at all → the direction state was undefined
  - this issue needs to be fixed

Version 3 – Goals

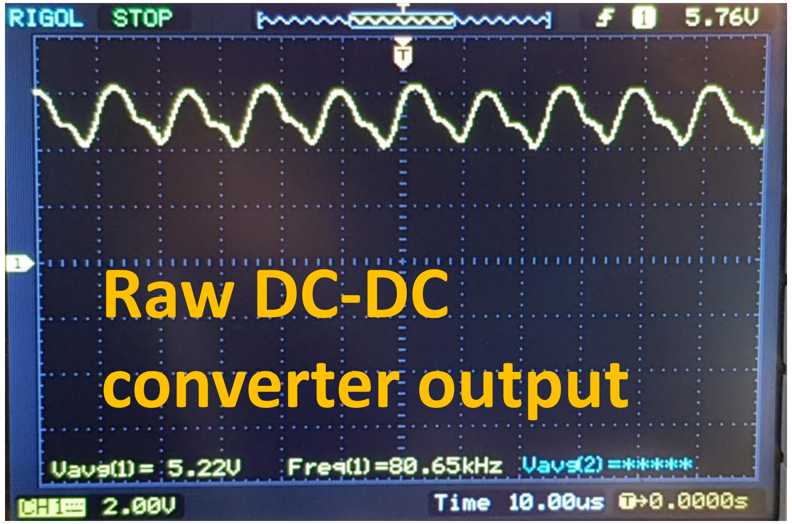
1. this version needs to have the fan tilted downwards, such that the bow is rising out of the water
2. power supply output filter needs to be installed because the voltage ripples of 2Vpp are too large
3. replace the 35 MHz RC system with 2,4 GHz system

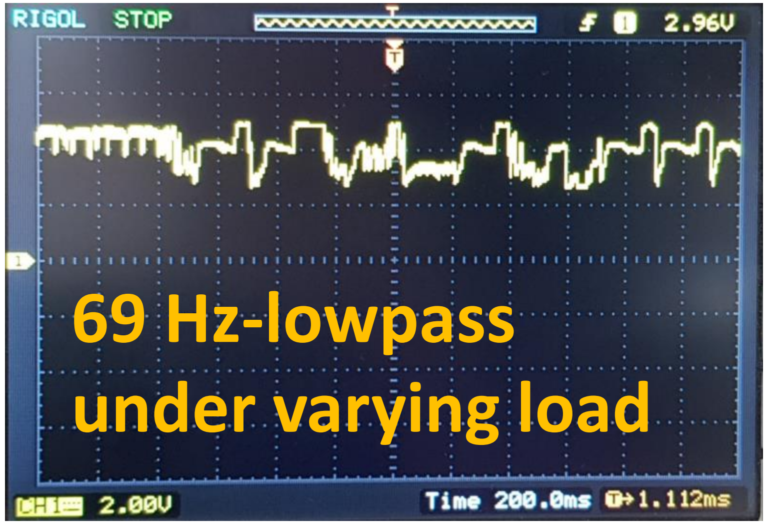


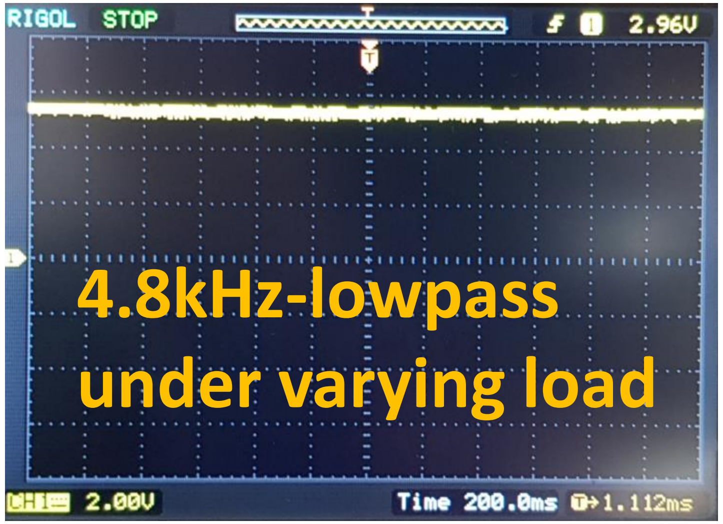


Version 3 – Build-up

- Power supply output filter needs to be installed
  - R-C-lowpass filter with a 330µF capacitor we get $f_c = \frac{1}{2\pi\ R\ C} = 4.8\text{k Hz}$ which is enough telling from the voltage plot over time
  - a 7 ohm resistor was tried, which would have created a 69Hz lowpass; though it smoothed the voltage, it was too slow to cover for the servos huge short-time power demands, therefore the resistor was removed and a 0.1Ohm resitance is assumed



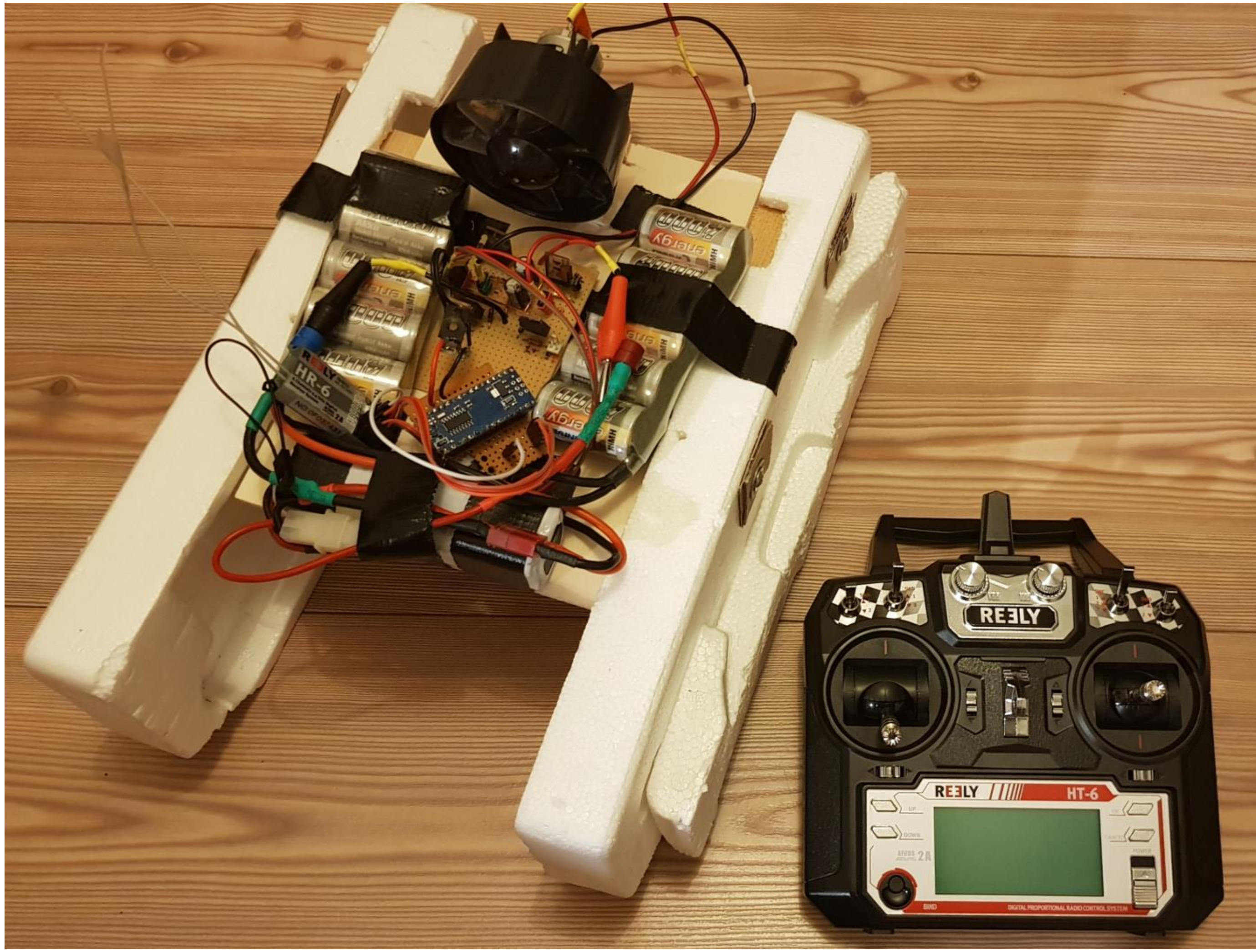




Version 3 – Build-up

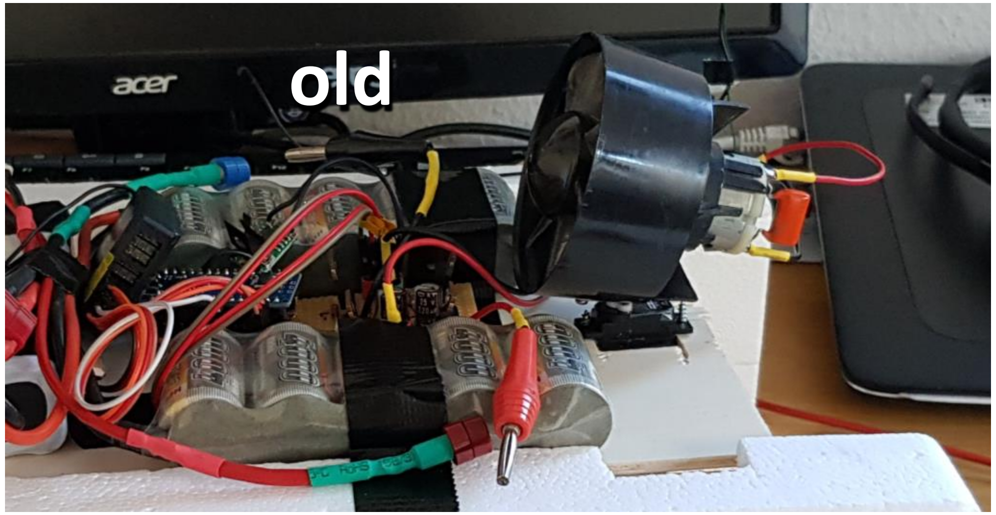
Neues System consists of

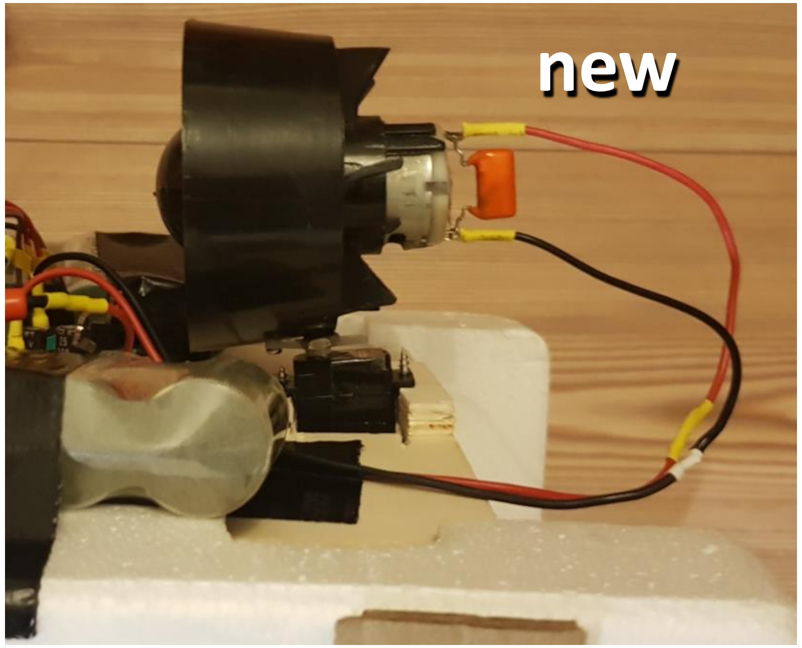
- 2.4 GHz sender and receiver
- 5V-DC-DC converter
  output capacitor (330µF)
- SW bugfix concerning
  fwd/bwd direction issue



Version 3 – Build-up

- New version also has an decrease fan tilt angle
  - Old: ~20°
  - New: ~0°



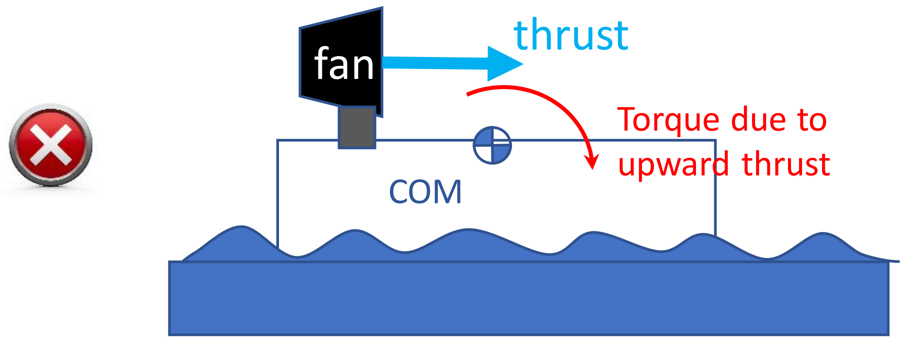


Version 3 – Build-up

- The new RC system has two freely programmable channels
you can assign switches to
- I chose to put switch A
on receiver channel 5
- I connected channel 5 with my previous input and tuned the fwd/bwd-switch threshold to 1500µs
because the switch generates a PPM signal on channel 5 that goes from
OFF-1000µs to ON-2000µs

Version 3 – Validation

- Boat is not tilting forward as much but still enough to cause a lot of drag
  - the tilting lever has decreased
  - reason for tilting:
    - fan being high above the batteries and
    - especially with the COM begin high above the water line the boat
- the batteries are unnecessarily heavy
  - currently: 21,6V, 18 NiMH cells with 3000mAh, weighing 940 g
  - Option 1:
    AAA NiMH → 18 AAA cells with 800mAh weighing 15g x 18 = 270g
    with wires and harness it would be around 300g
    → less than 1/3 with AAA batteries (amount of stored energy goes down the same factor)
  - Option 2:
    LiPo battery 6s with 22,2V and 3300mAh weighing 513 g



Version 4 - Goals

- design a completely new frame
  - 3d printed single shell in a similar shape as a real airboat →
  - Fan needs to be lower than before
    - Option 1: switch to a BLDC fan with a servo controlling fins behind the fan
    - Option 2: stay with the DC fan and get the best out of it