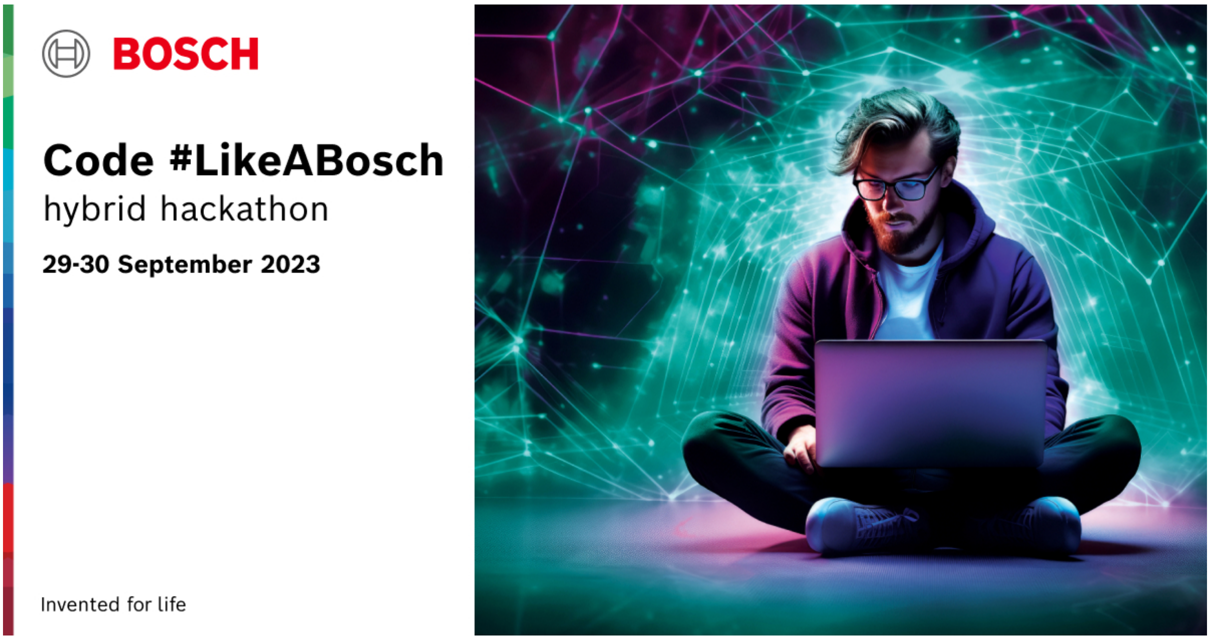
Project FÚRfang

Code #LikeABosch Hackathon 2023

Documentation



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Budapest, 29-30. 09. 2023

Introduction

About the team

Our team consists of a small friend group from the BME Suborbitals rocket developing competition team. The four of us make up a significant part of the Suborbitals` leadership. Therefore we are quite familiar with hardware and software development, short timeframes, and managing ourselves in tight competition environments. The common interest in space technology and time spent working together on demanding tasks made us a cohesive team with smooth communication and workload management.

Ábrók László Patrik

I'm studying computer engineering at BME, specializing in System design. I am passionate about embedded software engineering and system modeling. In the competition team, I lead the Avionics team, which is responsible for hardware and software development. In my free time, I enjoy reading, playing video games, and cycling.

Balázs Artúr László

I'm currently studying mechanical engineering at BME, but I also love all things electronics. My other passions are CAD modeling and machining. In the competition team, I manage the Recovery team, which takes care of bringing the rocket back to the ground in one piece. In my free time, I like to go hiking or just watch a good movie.

Farkas Ákos Márk

I`m studying electrical engineering at BME, specializing in high-frequency systems. I`m looking to work in the space industry in Europe. In the competition team, I`m a vice president, and I manage a number of different projects, mainly as a team lead engineer or organizer. In my free time when I`m not building a rocket, I like to play basketball, go for a hike, or go wall climbing.

Kováts Bence Csaba

I`m currently at BME space engineering MSc. My base degree is in electrical engineering. In the competition team I'm primarily working on the edge of engineering, for example, project management and event organization are one of my favorite tasks. For work, I`m developing MATLAB. In my free time I like to read sci-fi books, I like to swim and spend time outdoors.

Problem

Drilling is far from the easy task it looks like. Although drilling is a common task in the world, and anyone can drill a hole, we can do it much more effectively. In this project, we would like to introduce some potential improvable points which can make this task easier.

We tried to thoroughly examine the problem. We look from the user`s, the manufacturer`s and the industry's point of view. But we did not forget to keep the development cost under the potential revenue gain, therefore the development will be monetarily viable. There are non-monetary gains as well. For example customer satisfaction or the increase in available data. These considerations are also important to take into account.

When we talk about the improvement of a drill we have an easy and hard job at the same time. Easy, after all, it's a well-known everyday tool that is used widely. At the same time, it's hard because a drill isn't a complex tool. It satisfies the main task very well. In these cases we need to look into what the customer's unspoken needs are. These latent needs are what needs to be targeted. When we are able to improve such a common tool and make it more appealing so that the manufacturer can increase profit, everybody can be a winner. It's important to point out that overcomplicating a tool easily can be a disadvantage. We need to be cautious about the complexity as well.

In the following, we would like to show you our ideas and complementary services that can make the product more appealing for the customer as well as the manufacturer.

Market research

The market for cordless drills is expected to continue to grow slowly but steadily in the near future. A ResearchAndMarkets survey forecasts annual growth of 5.7% over the next 8 years. The social reasons cited are changing home habits (DIY is becoming more popular) and urbanization, but the main driver of change is the continued development of cordless drilling technology. (Bib. 1)

Users were positive about all the improvements (e.g. improved performance, variable user settings, more ergonomic design, additional applications) that made the tool more comfortable to use. The next big issues - and opportunities - include the issue of a more efficient and longer-lasting power supply. So, in addition to extra features, there is also a market opportunity in battery development. (Bib. 1)

Given these facts, our plans are certainly realistic and could cover significant gaps in the market. However, it may be advisable to diversify the market, i.e. to target a narrower range of users with upgraded drills, as there are some who are well served by the current range of tools and would not be willing to pay more for a more advanced one.

We can conclude from another article that similar smart tools can be extremely popular based on the fact that on Kickstarter a smart drill project generated 500% support. (Bib. 2) This product is very similar to our idea. The main improvement over the above-mentioned design is the IoT capability and the fact that we use the collected data a lot more. This data-oriented view has been popular since Industry 4.0 came out.

Estimating total revenue growth is more difficult. Our research on Kickstarter suggests that about 35% of people who use a drill would be interested in a more advanced drill (the support for complex drill development projects is about 1/3 of that for regular drill projects). (Bib. 4)

Current research puts the drilling market at $4 billion. (Bib. 3 & 5). The unit price of the Bosch EasyDrill 12 drill is around $70-100. Assuming that this is the average price, the market currently stands at 40 million drills. Bosch is currently one of the largest players in the market, so we assume that their market share is around 33%, meaning that they have around 13 million users of their product worldwide. If 35% of those users switched to our improved product, that would mean 4.5 million new tools, which, on top of the original product profit, could mean up to $100 million in total extra profit on top of our $25 profit per unit.

Ideas

During the hackathon, we had lots of ideas. We tried to examine them as thoroughly as possible.

Implementable ideas

Distance measurement

The sensor is facing towards the tip of the tool (toward the drill bit). If the user calibrates the drill with the installed drill bit, the display will show the distance traveled by the drill into the wall, basically measuring the depth of the hole. The depth is useful data in itself, but with some preset, and the motor controller it can do even more. If we want to drill a hole of known depth, for example in the case of anchor install, you can preset the distance, or pre-measure the distance with the tool itself. In this case, the drill can prevent overdrilling by controlling the motor current which can be extremely useful when dealing with thin walls such as separator walls in panel houses. The control behavior is challenging to tell because there are lots of ergonomic considerations to the shutdown process.

Based on the distance traveled we can calculate the speed of drilling. If we measure the torque as well we can conclude the state of the drill bit. For example, the decrease in speed or increase in torque can indicate a deteriorated bit tip.

Gyroscope

The orientation of the drill is useful to know if we want to drill a hole perpendicular to a wall, or any angle we want. If we use the base of the accumulator to calibrate the orientation of the surface we can set any reference frame for the angle of drilling. It can be useful in case we want to hide a screw in wood.
We can detect smaller vibrations in the system too. It can indicate a slipping bit in a screw. The drill can warn us to prevent the destruction of the bit and the screw.
Some types of vibration can be a sign of a failure in the motor or gearbox. The system can recommend maintenance in these cases.

Force sensor

If we integrate the force sensor sticker at the right place we can calculate the torque acting on the user and the drill. Some further uses are not mentioned above. Sudden change in material, for instance, reaching metal rebar in concrete walls or hitting insulation in a wood wall. In these cases, the drill can show an error or can control the motor speed.
The fusion of gyro and torque sensing can show us holes slipping inside of brick walls when a cavity is hit. In this case, it can show a warning and stop the drill.

H-bridge

In case of tapping after reaching the required length, the motor can reverse direction to make the process as fast as possible.
We can also slow down the drill in case of a detected hazard or failure.

IoT

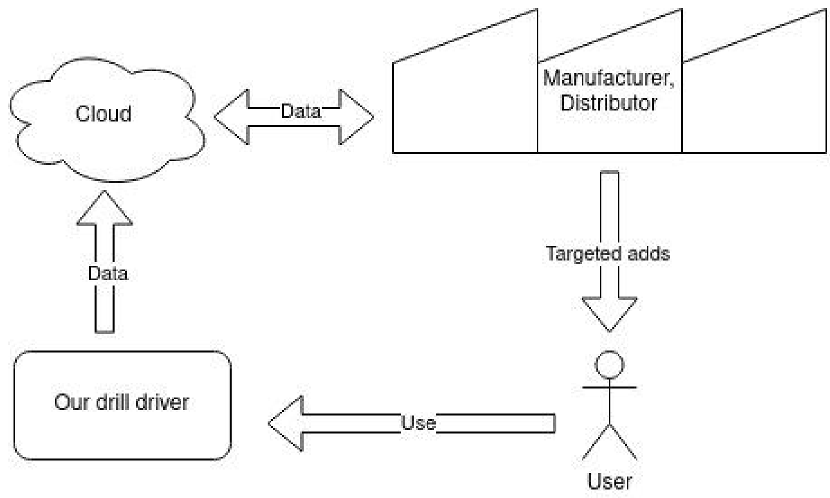
With the help of the ESP`s internal Wi-Fi module, we can upload the collected data to the internet, where both the manufacturer and user can reach it. For a construction company, the deterioration data is very useful for management purposes. For the manufacturer, it opens the chance for targeted ads and the collection of lifecycle data about the device.
With sensor fusion, we can collect a number of other statistics. The number of drilled holes is relatively easily deductible. Creating statistics in the cloud will benefit the customer and the manufacturer.
The cloud can host possible lookup tables. For example, anchor suggestions based on material and load.
With some added laser sensors positioning based on distance measurement can be achieved. With this, the drill can navigate you through a series of holes precisely. Integration with interior designer software can supply the necessary position list. But in simple cases it can also find a divider point on the wall, such as the middle of the wall 1.7m from the floor.

Discarded ideas

- Gimbal stabilizer
  We imagined a chuck replacement with a complex motorized gimbal mechanism to compensate for the twisting motion of the user. It's not just an incredibly complex yet useless piece of engineering because it can't compensate for the shift in position. We thought about a system with two gimbals to allow the system to compensate for positional shifting, but the length of the geartrain becomes ridiculous. It would be a better option to put a drill on the gimbal rather than the gimbal to the drill. But in that case, you just rediscovered industrial robotics.
- Wireless charger for drill accumulator
  This idea isn`t far from plausibility; it is just a completely different piece of equipment. This device should be integrated into the battery, with the complementary charger station.

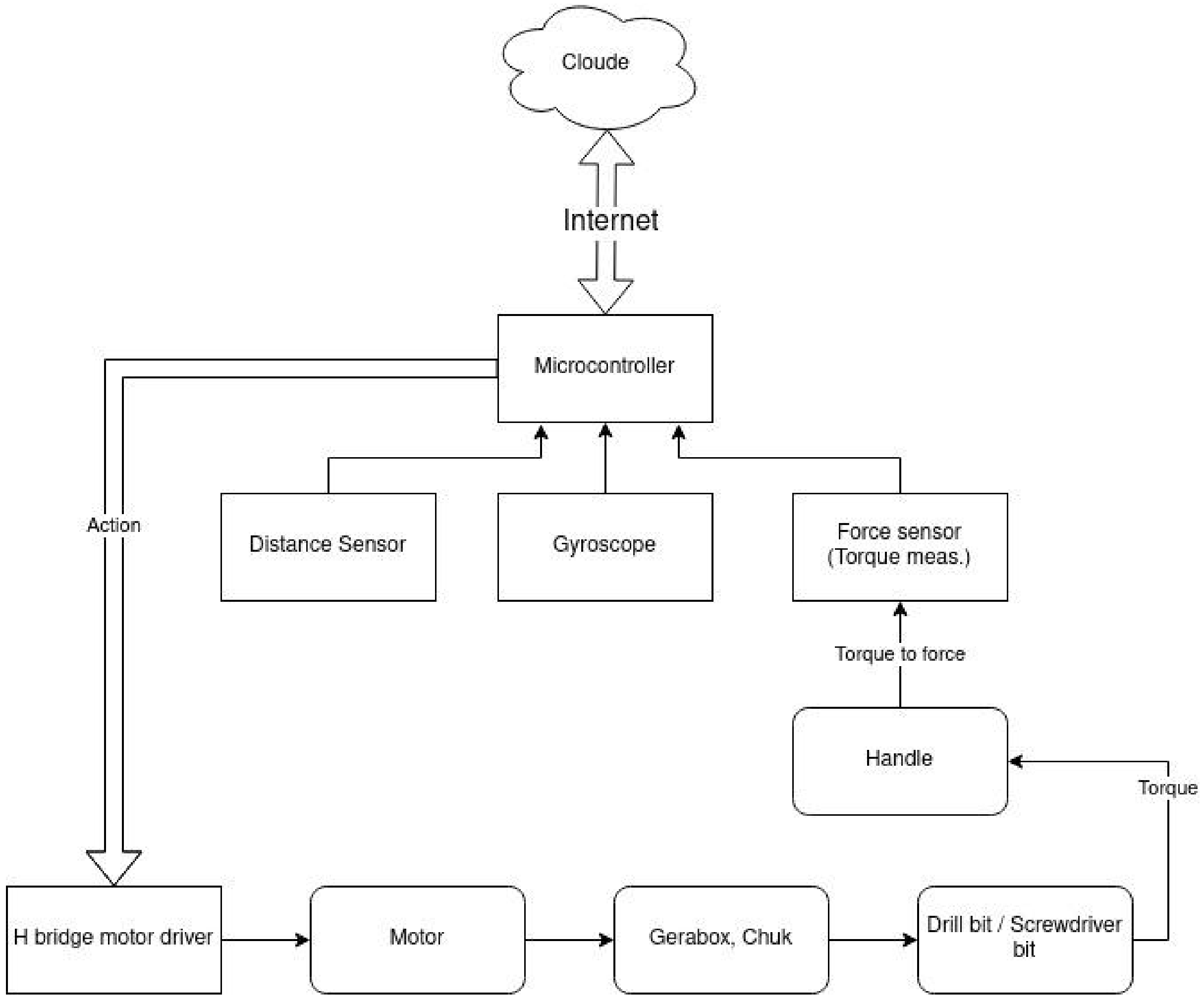
Functions of improved product

The previously mentioned functions make a long list. To avoid overdoing the development we choose a set of tools and sensors and try to limit ourselves to the most promising ideas. Simple hardware is cheaper and more reliable. The list of use cases is still long, but more manageable. Lots of opportunities are in the data processing and support software, which is not our main scope in this competition.
The basic operating loop of the product is as follows:



Picture 1.: Business model

This loop model maintains a connection between the manufacturer and the customer, improving the chances of rechoosing the brand. Furthermore, the information and utility gained by both parties benefit the entire product life cycle.
This cycle is aided by the product design. The following diagram summarizes the basic workings of the tool.



Picture 2.: High level block diagram

Hardware & Simulation

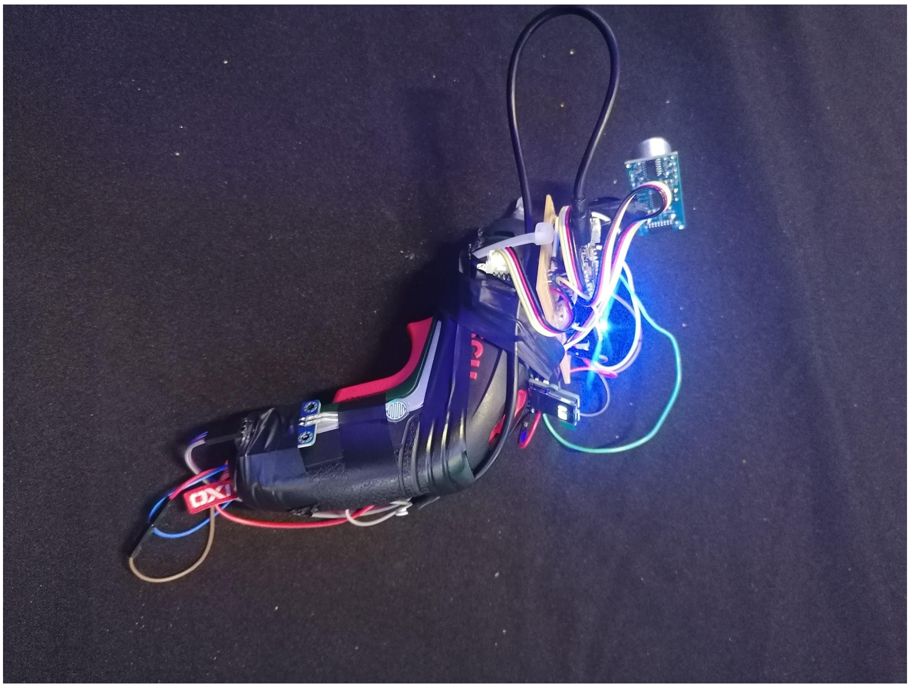
Bill of Materials

Based on the CAD plans, a price estimate has been made, the table of which can be found below. The prices are wholesale prices, taken from the websites of various manufacturers and distributors. If we add development and other costs, we can expect an increase in unit cost of about 25 €. However, market research suggests that users would pay up to 50 € more.

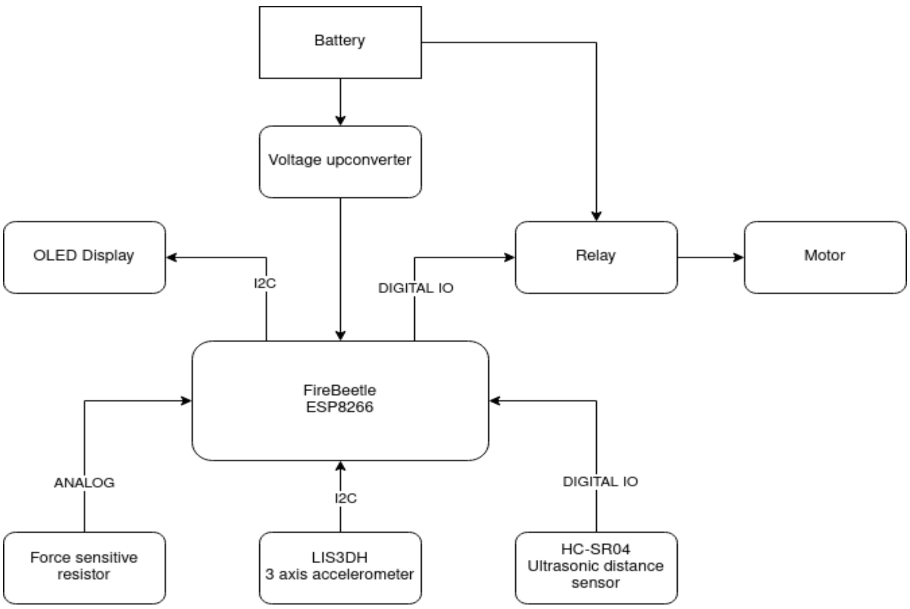
#	Reference	Qty	Value	Cost/db [€]*	Cost/Unit [€]
1	C1, C7, C8, C15, C17	5	10nF	0,04	0,20
2	C2, C3, C4, C5, C10	5	22uF	0,057	0,29
3	C6, C9, C16	3	10uF	0,045	0,14
4	C11	1	4,7uF	0,044	0,04
5	C12, C13	2	1uF	0,038	0,08
6	C14	1	2,2uF	0,083	0,08
7	D1	1	SM4007	0,1	0,10
8	D2	1	1N4148	0,01	0,01
9	L1	1	10uH, 50mOhm	2,00	2,00
10	M1	1	Motor_DC	0	0,00
11	Q1, Q2, Q3, Q4	4	DMN3404L	0,056	0,22
12	R1, R2, R3, R4	4	10k	0,058	0,23
13	R5	1	R_Forcesens	1	1,00
14	R6	1	510k	0,05	0,05
15	R7	1	105K	0,05	0,05
16	R8	1	20K	0,05	0,05
17	R9, R11	2	4,7k	0,05	0,10
18	R10	1	390k	0,05	0,05
19	U1	1	LIS3DH	1,94	1,94
20	U2	1	ESP-12F	1,42	1,42
21	U3, U4	2	MIC4604YM	0,725	1,45
22	U5	1	HC-SR04	1,14	1,14
23	U6	1	TPS560200	0,687	0,69
24	U7	1	AMS1117-3.3	0,08	0,08
25	U8	1	64x48_OLED	3,42	3,42
* based on online supplier data		** for information only		**Sum****	**14,83**

Schematic

Besides the design challenges, we made a prototype of our proposed circuitry. It is made mostly from development boards and a battery powered screwdriver serves as a replacement for the drill driver.



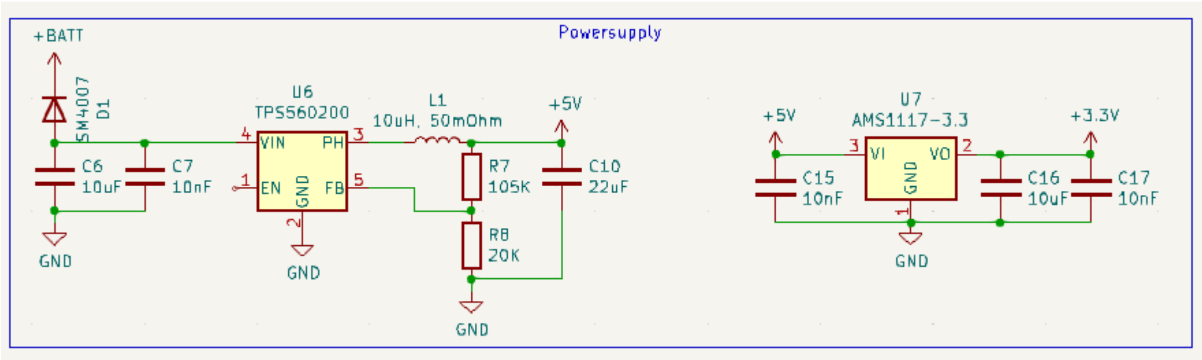
This block diagram represents our simplified solution with materials at hand at the site of the hackathon. Instead of a full H-bridge motor driver, we used a relay to turn off the drill when the desired drill depth was reached. Also, we used the tool's internal batteries with the help of a boost converter to provide power to our improvements. The arrows represent the communication forms between the modules used.



Picture 3.: Block diagram of prototype

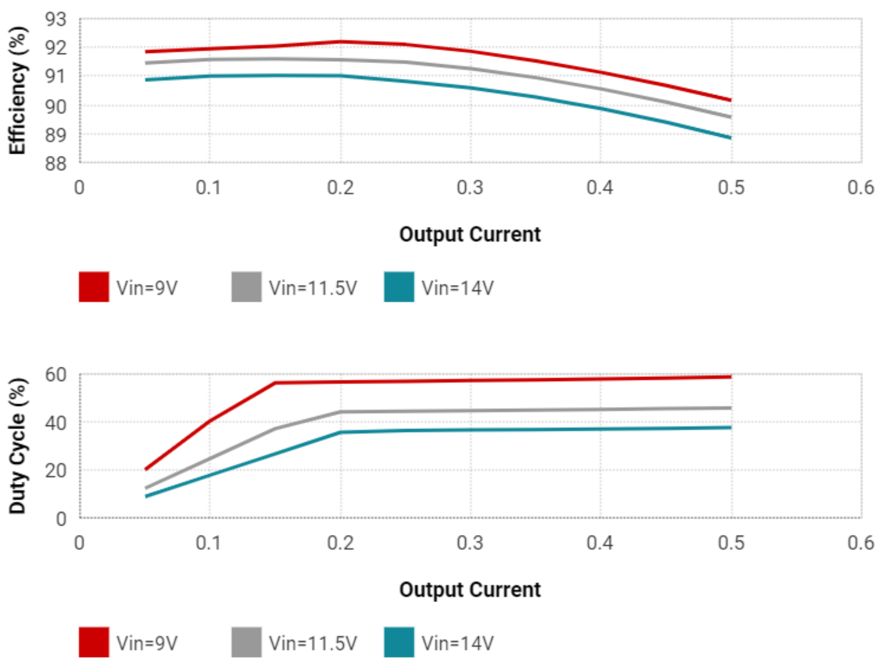
Power supply

Our additional electronics are powered from the drill's own battery. To provide the necessary voltages first a switching power supply makes 5 volts from 9 to 14 volts on the battery. It can provide up to 500 mA, which is adequate, based on the current draws provided for the planned components. To create and simulate the power supply we used the Texas Instrument reference design tool. (Bib. 6) The 3.3 volt is made with a low dropout regulator. For both power rails, filtering capacitors are used.



Picture 4.: Power supply schematic

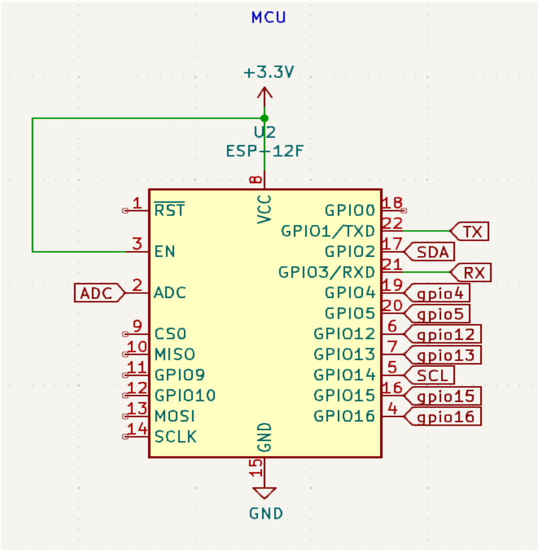
The tool contains simulations for the characteristics:



Picture 5.: Power supply simulation

Microcontroller

We chose the ESP-12F microcontroller. We had a lot of experience with ESPs, and the wifi capability is necessary for IoT devices. As this is intended for series production the parts necessary for programming are omitted.

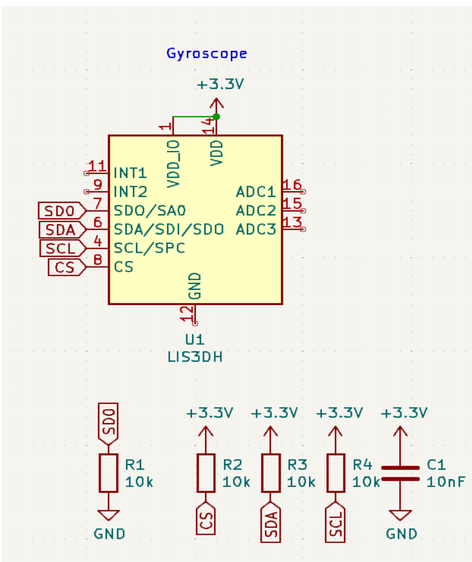


Picture 6.: Microcontroller schematic

Sensors

Gyro

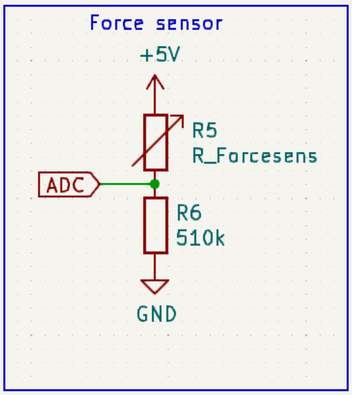
We use the Grove - 3-Axis Digital Accelerometer board. The communication uses I2C, therefore the schematic contains the appropriate pull-up resistors and some filtering condensators.



Picture 7.: Gyroscope schematic

Force sensor

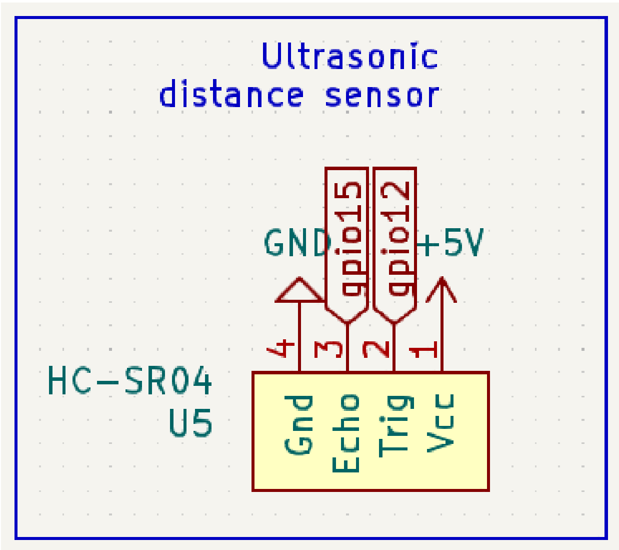
The force measurement is based on a variable resistance measuring sticker. The variable voltage divider creates a voltage signal proportional to the force acting on the stamp.



Picture 8.: Force sensor schematic

Ultrasonic distance sensor

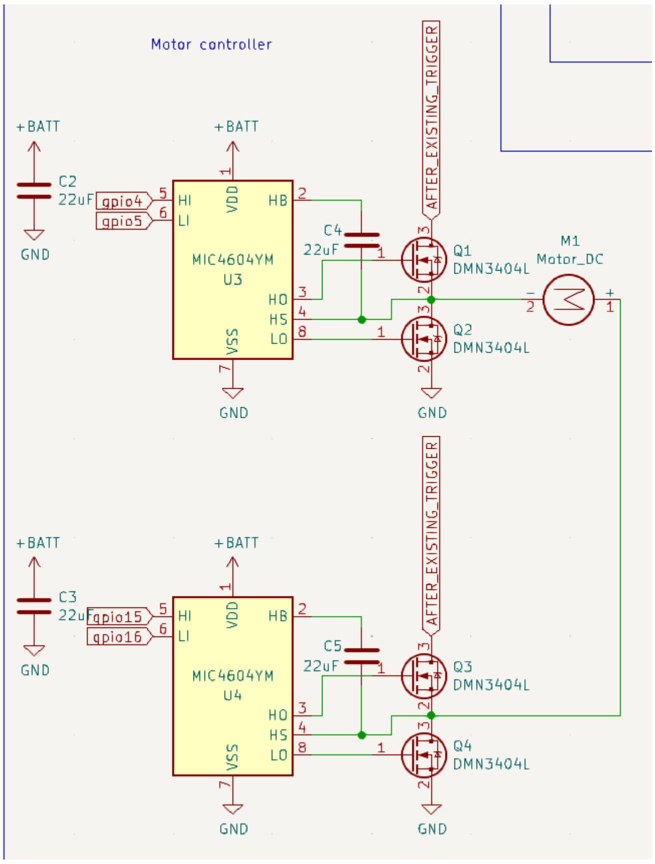
This is currently based on a development board, but later can be changed for a more appropriate one.. We chose it, because the HC-SR04 is a well-known sensor in DIY electronics therefore it's easy to use premade code segments and libraries to manage the sensor.



Picture 9.: Ultrasonic distance sensor schematic

H-bridge

We designed a motor driver H-bridge based on two half bridge drivers and mosfets, which are suitable up to 5 A of current draw. This driver is placed after the drill's original trigger. So the motor driver can only stop or reverse the rotation when the operator is pulling the trigger.

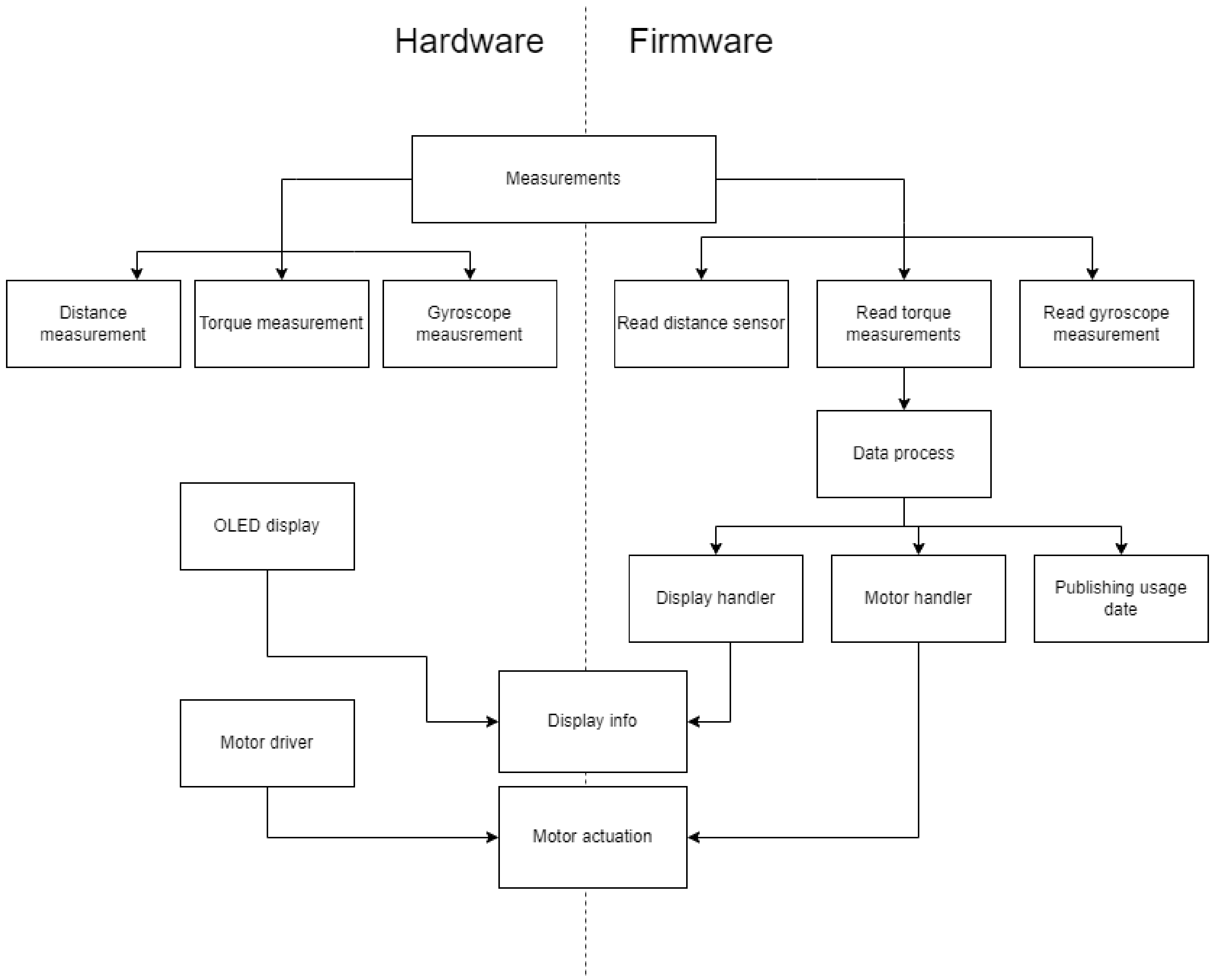


Picture 10.: Motor controller schematic

Firmware

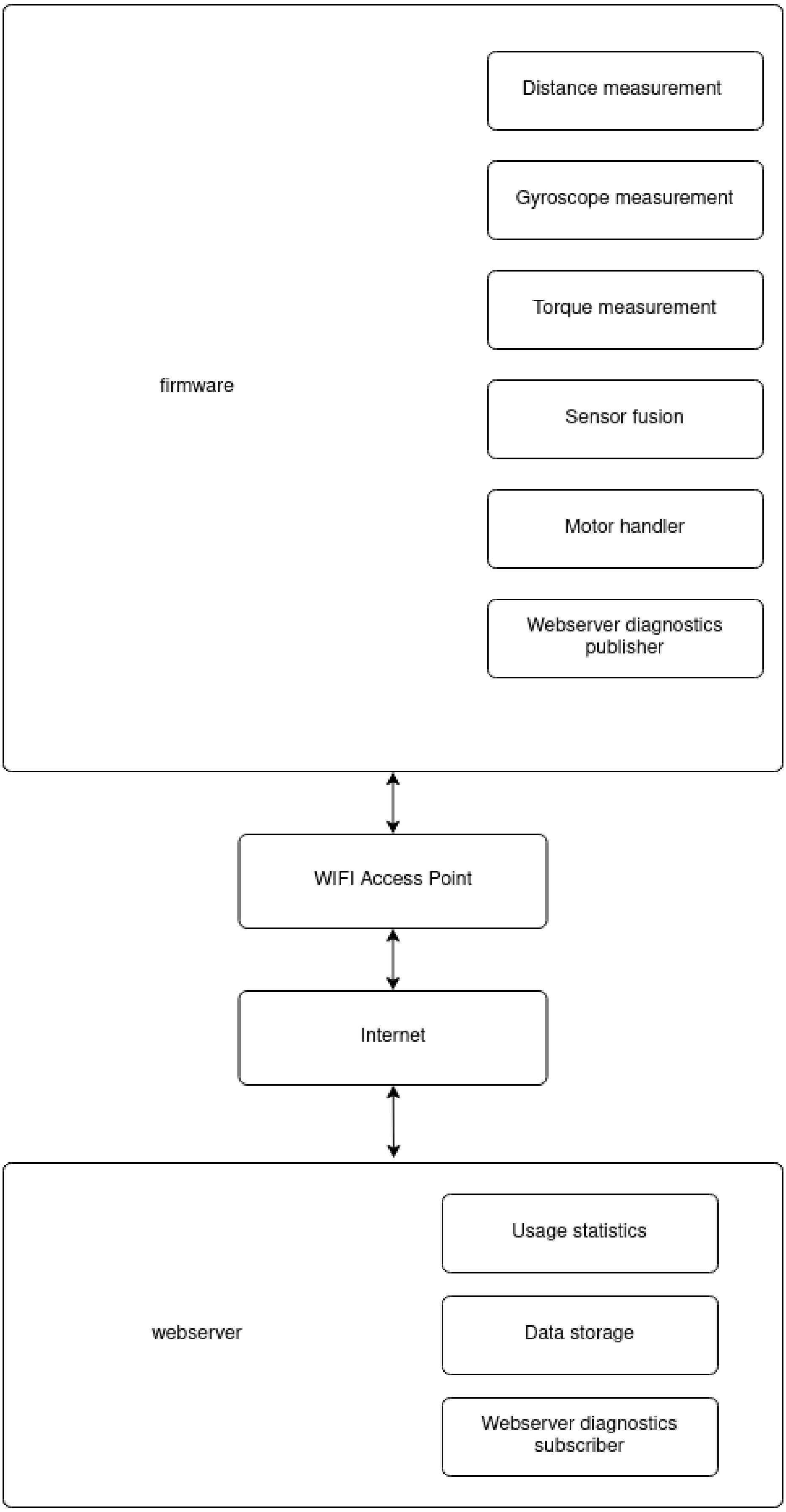
The diagram below represents a high-level functional block diagram of our hardware and firmware design. The measurement functionality is derived into 2 branches according to the domain of realization. The measurement itself is conducted by some of the provided modules.

Firmware functions and hardware platform allocation	
Module	Firmware function
HC-SR04	Distance measurement
FSR07BE	Torque measurement
LIS3DH	Gyroscope measurement
SSD1306	OLED display



Picture 11.: Firmware design block diagram

The code base of firmware is written in C and C++. For measuring we used several libraries. The sensors explained in the figure above have been implemented. The software does not currently include an IoT implementation, but could be upgraded without any further effort.



Picture 12.: Extended firmware block diagram

Possible development directions

Future development should look into the possibilities of lifetime management for increased lifetime. Battery management circuits can significantly reduce the degradation of cells. Other direction can be electrical enhanced power for the tool. Create boost modes to achieve greater torques without the need for higher voltages.

Conclusion

This idea covers lots of ground. Aldo the electrical design is simple, the support infrastructure needs to be bild for optimal operation. For the home builder this solution can be a great and interesting tool for easy installations, but the main advantage is in industrial use, where drill tasks are repeated. For the industry it can be a huge efficiency booster boot in work and in maintenance. The precalculated cost show that whit de projected interest the upgrade can be viable.

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