KOLT

A smart cooler for your festival camp

41028 Design of Mechatronic Systems 2

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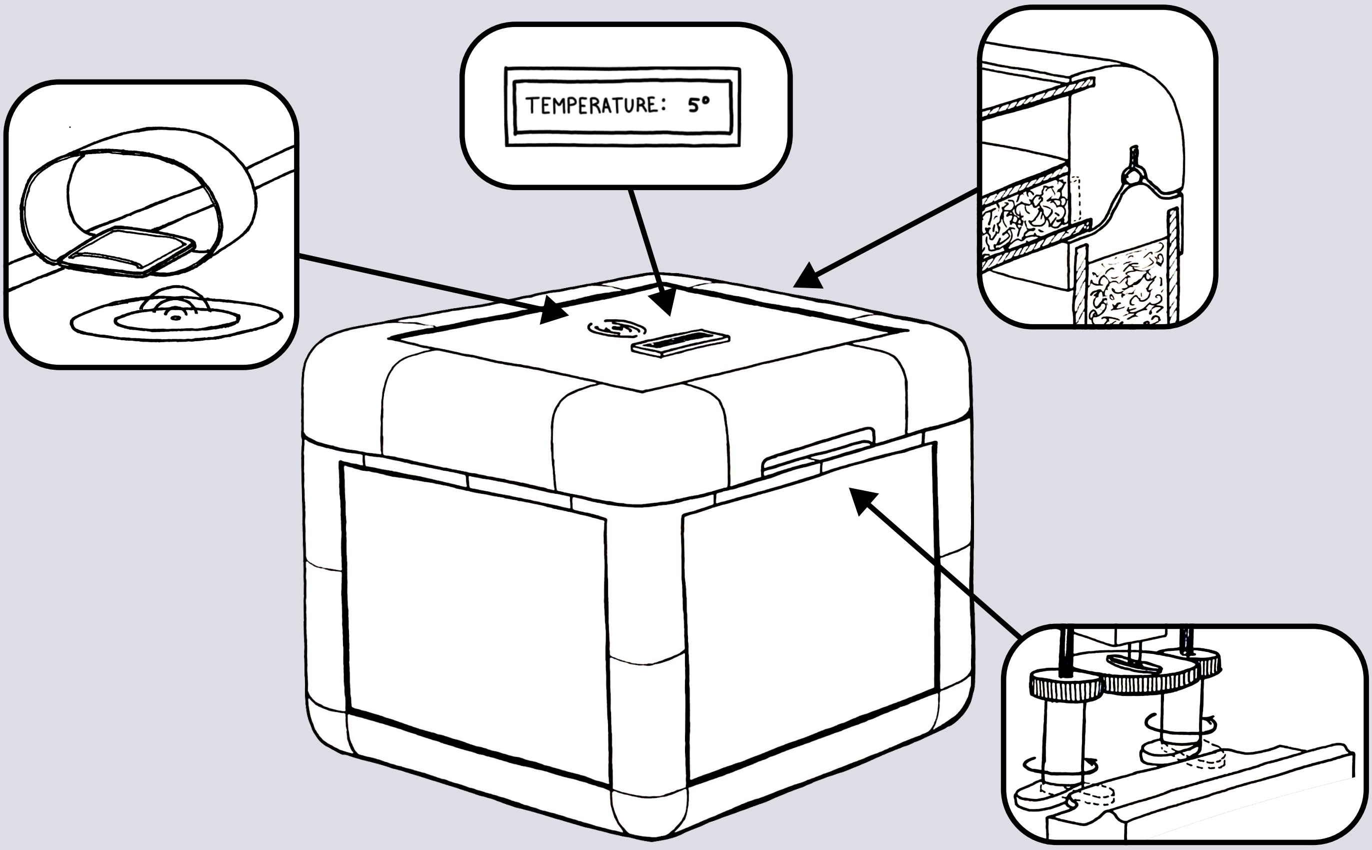

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1. Introduction

A recurring issue at Roskilde Festival is the challenge of keeping food and drinks cold during hot festival days. Without access to proper cooling, food can spoil quickly, which not only leads to waste but also increases the risk of people getting sick. In response to this problem we are introducing KOLT - a smartcooler to keep your food and drinks chilled, all festival long.

KOLT is built around a rental system, where guests can reserve a cooler with a cooling element. During the festival, users can exchange the cooling element at designated stations, similar to how people swap power banks with Volt. This way, food and drinks remain cold and accessible throughout the festival. The goal of the project is twofold: to improve the overall camping experience and to reduce food waste produced on the festival site. Our primary target users are camping festival-goers, who want a reliable solution to keep their food and beverages fresh without constant trips to the supermarket.

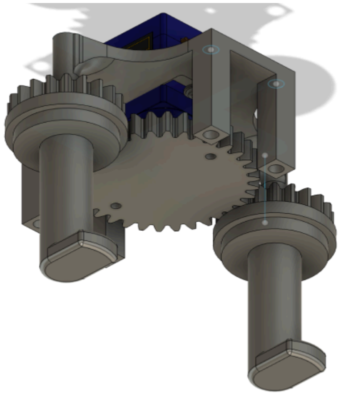
This report outlines the development of a beta prototype of the KOLT cooler. Over a three-week period, the concept has been tested, refined, and evaluated. The following pages describe the final concept in detail, assess the prototype's performance, highlight key stages in the design process and offer reflections and suggestions for future improvements.

2. Final Concept

The final beta prototype for KOLT is a compact, insulated cooling box designed for Roskilde Festival. Measuring 35,2 cm x 35,2 cm and with a height of 34,9 cm, the design balances portability with practical storage. The box features 3D-printed corners and edges that securely hold 3 mm thick acrylic plates, which encapsulates 20 mm of styrofoam insulation.

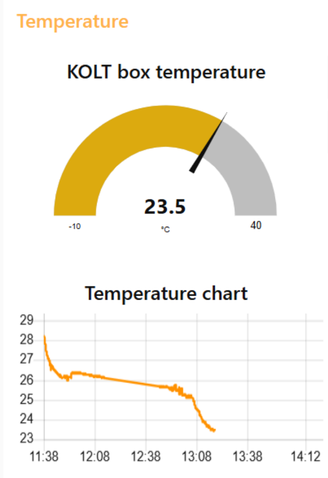
The outer acrylic plates are colored orange to align with the visual identity of Roskilde Festival. The interior is kept white to maintain a clean and minimal look. The lid is constructed as a layered “sandwich” of acrylic, electronic housing, styrofoam, and lastly another layer of acrylic to close the lid off. Around the edge of the lid, a sealing rubber strip has been added to ensure proper closing.

Inside the box, a small compartment is designated for the cooling element. This cooling element is designed with an integrated handle, making it easy for users to transport between the booths where they are handed out and their campsites. This feature responds to festival-goers' need for a convenient cooling solution.



The box includes a locking mechanism that can be unlocked using the RFID chip in the wristbands, which are provided for the Roskilde Festival. This feature ensures that no unwanted guests can steal your food and drinks while you are away from the camp.

To keep track of who can unlock the box, a feature is added where the ESP32 stores the RFID tag of the wristband in its internal memory after an initial “add new key” process. This list of valid keys are sent over to NodeRed through MQTT communication, so the user can keep track of who has access to the box. Here it is also possible to manually add more wristbands to the list as well as remotely unlock the box if needed.



Additionally, the box monitors its internal temperature constantly and sends this data to NodeRed, which is then shown on the NodeRed Dashboard App. The display on the lid also shows the current temperature in the box. NodeRed will send out a notification when the temperature reaches a threshold of 10 degrees, so the user is notified when it is time to substitute the cooling element.

3. Prototype Evaluation

Throughout the project, the box has been developed in iterative steps to see which solution would work the best and optimize the box. The current prototype represents the final beta version, where all key components are assembled and evaluated together. The prototype closely reflects the intended final product in terms of form, function, and materials.

The final prototype is a fully functional cooling box that measures temperature, locks via RFID, and includes a designated compartment for a cooling element, while also incorporates the user via the NoteRed app with different functions such as temperature measurement, a remote unlock function, add new key function and an overview of the currents keys. While already close to a final product, a few improvements, such as using a lighter, water-resistant material and enhancing the insulation, would bring it even closer to a market-ready solution.

How did we test?

Several aspects were tested to evaluate the performance and feasibility of the box:

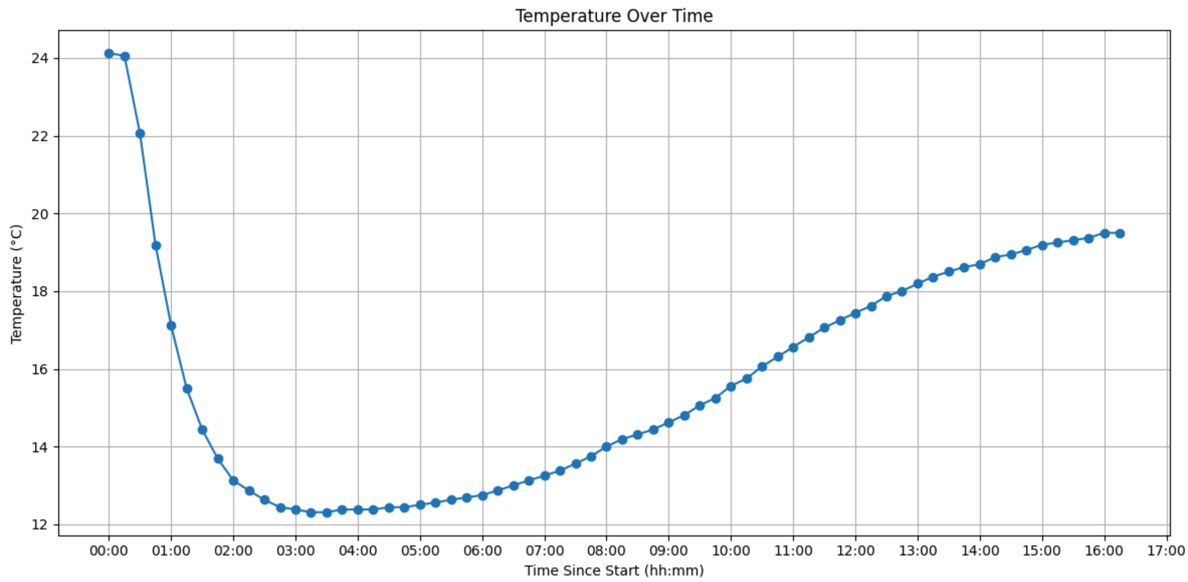
- Fit and assembly testing: Components such as the lid, sealing strip, and hinges were tested for dimensional fit and ease of assembly by multiple iterations. This included repeated mounting and dismounting of the lid and incorporating the electrical parts as well.
- Insulation testing: The shape and placement of the sealing strip were tested using different variations to assess airtightness and insulation efficiency.
- Durability and handling: The structural strength and stiffness were tested by assembling and manipulating the box multiple times to simulate regular use.
- User evaluation: Informal peer feedback was collected to evaluate usability and perceived robustness. As well as a final test of the beta prototype in regards to checking whether or not the box actually could keep cold.

To evaluate both our subsystem iterations and the final beta prototype, we used the following criteria to determine how relevant and functional the prototype is:

- Fit: All parts must assemble correctly without force or adjustments.
- Functionality: The box must close tightly and allow repeated opening and closing.
- Reproducibility: The prototype must reflect a design that can be manufactured with consistent quality.
- Integration: Subsystems (walls, lid, hinges, sealing) must work together without conflicts.

Overall, the final box meets the established criteria, but there are still certain elements that do not fully comply with all of them. When assembling the box, the acrylic plates and 3D printed sides were a snug fit, requiring the acrylic to be sanded down to fit properly. Therefore, the fitting aspect of the prototype needs to be adjusted in future iterations.
Another crucial aspect of the cooler is its ability to maintain a low temperature without requiring frequent replacement of the cooling elements. Based on our test of the coolers we bought - which maintained a low temperature for 6 hours, we established a criteria that our beta prototype should meet the same minimum cooling duration. To test this, we evaluated the final prototype using a single cooling element. The result showed that the box maintained a low temperature for the full 6 hours, which we were very pleased with, although it was not

able to cool down to a level similar to that of the bought coolers. This is likely caused by our material choice and small gaps in the assembly, which is definitely something to improve in future iterations. In this case, we would expect a performance level comparable to that of a standard cooler. A graph showing the temperature over time can be seen below.



The graph also shows that the minimum temperature is around 12 degrees, being above the 10 degree limit for the swapping of cooling elements. This could be caused by the temperature sensor being placed at the top of the box instead of at the bottom where the temperature is lowest. We also tested to see how precise the temperature sensor was, and found that the sensor was actually off by 2-2,5 degrees celsius at room temperature. Overall the box fulfilled the requirements set by the group, but including another cooling element in a future test could probably keep the box even colder and hold that for longer.

4. Key Aspects from the Process

From the 13-week course we had already defined our user needs and technical requirements following the V-models first few steps. With a low fidelity alpha prototype we continued in the 3 week course by dividing our whole system into subsystems. We tested each subsystem, such as the locking mechanism, temperature sensor system, and mechanical structure individually.

During sprint 1 we quickly realised that, although we had hoped for many of the iterations to progress in parallel, this was often not possible due to the high level of integration between the components. One part depended on the completion of another, and so on. This was at times a big setback for the different teams.

In sprint 2, we recognised the need for a better workflow - not by isolating our subsystems, but by creating a continuous flow between them. To support this, we began each day with scheduled morning meetings. These meetings kept everyone aligned, clarified where support was needed, and gave a clear overview of the progress across subsystems. This helped us turn initial frustration into productive collaboration, allowing us to focus our efforts where they had the greatest impact.

The meeting gave a great overview but we were still faced with a lot of challenges. One of the greater challenges in our process was the choice of material. By using 3D print as the main process we experienced a very time consuming development process. If one small thing was changed like the gearing of the locking mechanism, or changing the shape of the lid and box, this would cause a setback in the whole integration and assembly of the full box. This is very clear in our sprint 2 where most of the 3D printing was done resulting in almost no integrated systems for the box.

Throughout the project, we experienced that system integration - typically seen as the last step in the V- model - is not only a one time event but an ongoing process that affects the entire process. Each subsystem was dependent on each other and underlined the importance of early testing, tight communication, and flexibility in prototyping as we see it with the assembly between box and lid.

Working with a mix of low- and high-fidelity elements made it easier to make quick decisions. For example, laser-cut cardboard versions of the acrylic walls allowed us to test hole placements before committing to the final cuts. This saved both material and time, and helped reduce errors during final assembly.

With limited time during the three-week sprint, we were forced to make some decisions based only on assumptions to make sure further work could be done, keeping the process in a constant flow.

5. Reflections and Future Improvements

Looking back at the development of KOLT, several challenges and insights have emerged that would be helpful for future iterations of the product.

One challenge we faced that proved more difficult than expected, has been ensuring that the box is water resistant while still maintaining usability and safety (especially around food storage). Food safety is a very important aspect that we could have looked more into, as this would be very important in future iterations of the box, including better sealing and using certified food safe materials.

The chosen manufacturing processes (i.e 3D printing and laser cutting) proved to be quite time consuming. In a real world production scenario it would be much more efficient to mold or cast the box, and then implement the electronics afterwards. Our manufacturing made sense in this prototype scenario, but would not be ideal for a scalable production. This is also because of the weight of the prototype. Due to the choice of using acrylic, the box is significantly heavier than expected. This was a constraint we had to work with due to material availability in the workshop, and is not a representation of our ideal material choice.

We also identified a potential issue related to the power supply. The box relies on a powerbank that fits in the lid. If it runs out of battery or breaks, the user would not be able to access the contents of the box, as it is sealed. Future iterations could include a dedicated powerbank compartment and a snap-on lid to allow easy access and charging.

With that being said, our beta prototype has successfully validated several core functions. The electronics work exactly as intended, and this gives confidence in the feasibility of the idea. This current prototype has provided many valuable insights that will influence the next iteration directly.

Overall, we are proud of what we have achieved from this beta prototype. Although there are aspects to improve, our core idea has been proven functional. A lot of the mechanical design was carried over from our Alpha prototype, which helped us build a product that could survive an environment as demanding as the Roskilde Festival. With a larger budget and more time, the design could be refined to improve usability, reduce weight, and increase the efficiency of the production - all while hopefully staying true to the main goals and idea of KOLT.