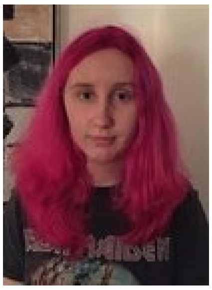
Technical University of Denmark

31015 Introductory project Electrotechnology

MEK1 solarcar - Group 4

Paper



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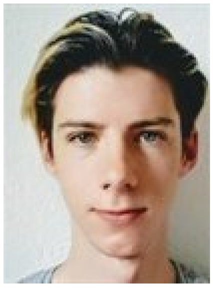

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Spring 2020

1 Abstract

In 2021 DTU ROAST will compete in the Bridgestone World Solar Challenge in the cruiser class. This is a large University project that is divided into smaller teams. This paper will give a short overview of the rules and regulations of the Solar Challenge, while diving into more technical detail for the Electrical Peripherals Team.

This paper will discuss the planing and execution of ideas designed by the peripherals team along with some of the challenges they ran into. This includes the designing and building of a prototype steering wheel that will house electronics for control buttons and a display meant for controlling varying functions legally required by road vehicles in Australia, such as; turning indicators, horn, lights and window wipers.

Due to restrictions set in place as a response to the COVID-19 pandemic, the available resources where very limited and the project could not be fulfilled to its fullest potential. However, a functioning prototype was built, which included some of the necessary functions, such as; indicator lights, window wiper speed and headlight mode.

2 Introduction

For our introductory project we became part of DTU ROAST, formerly known as DTU Roadrunners Solar Team. DTU ROAST is a division of DTU Roadrunners that only focuses on solar powered vehicles. The year 2021 will be the first year that DTU competes in the Bridgestone World Solar Challenge, as part of the cruiser class.

In the cruiser class you receive scores based on "payload, energy consumption and a subjective element of 'practicality'". You will also receive extra points for every extra front facing person you have in the car. The car has to be able to drive 1200km without recharging as part of three stages of a trip between Darwin and Adelaide, only relying on the solar panels it is outfitted with[1].

Our team was tasked with designing the peripherals that will later be implemented in the car, but as part of our introductory project we would mainly be focusing on designing the steering wheel.

This steering wheel needs to be able to control the direction of the car and the peripherals such as lights, horn and wipers. We are not making the steering mechanism itself, but we do have to make the steering wheel is compatible with the rest of mechanism. Furthermore to not be disqualified we have to make sure it follows the competition rules. Then there are extra features and attributes, such as having the steering wheel be road legal in Australia, energy efficiency, and practicality which are arbitrary parameters which are determined by the judges. However the end goal is simply to build a steering wheel that can send signals to the peripherals, all other features are nice to have, but are not strictly necessary as we are very time limited.

However, due to the global pandemic a lot of our goals and plans had to be scrapped and our priorities re-evaluated, as mentioned throughout this paper. DTU was forced to close as part of the government response in March, and thus most of our resources and lab access were made inaccessible.

3 Main

3.a Steering non electrical design

As part of the competition we have to drive a very long distance with no opportunity to fix broken pieces, this meant we had to design a structurally sound and reliable steering wheel. After consulting with the Mechanical Engineering team, we discovered that our earlier iterations of the steering wheel did not meet these requirements. We had made the joints from the wheel center to the outer ring too square, which resulted in a very brittle design. We amended this by making the joints wider and rounded the edges. This design should be durable enough, but since we didn't have access to a 3D-printer we had no way of testing the durability and strength.

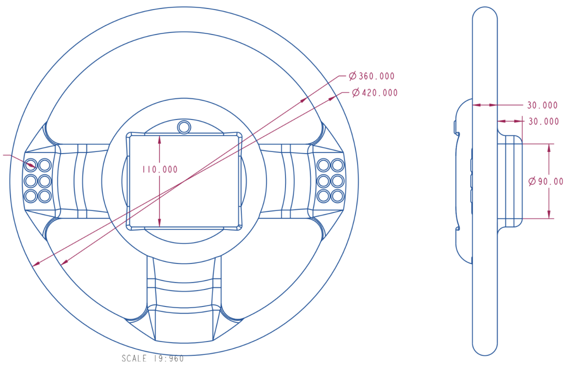

Figure 1: Diagram showing dimensions of the steering wheel.

We were able to salvage a steering wheel from a car sent to recycling. The steering wheel was salvaged from a Citroën Berlingo 2003, which is about the same size as our steering wheel measurements, only about 4 cm smaller in its outer radius (38 versus 42), but it allowed us to get a better idea of the button placement and we planned to cut a hole in it to fit the display and buttons, but since our display didn't work (see the display part of this paper for more details), we ultimately decided not to do anything with it. Below you can see what our final design was (since we were low on time we didn't make a CAD drawing.)

Figure 2: The Citroën Berlingo steering wheel

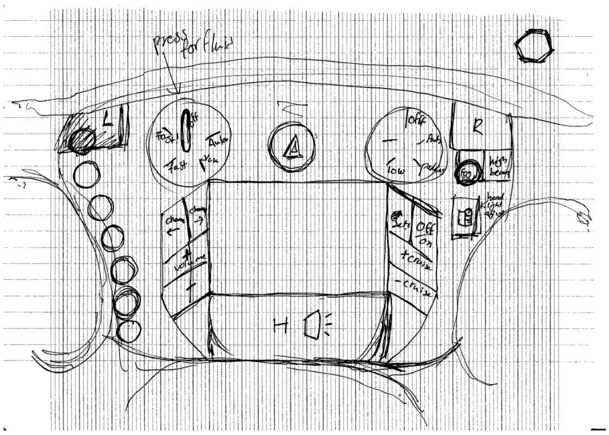

Figure 3: The rough sketch of the final design of the steering wheel, modelled after Berlingo wheel

We had a meeting with the Electrical team about which functions they required being mapped to the buttons, and we looked through the regulations to make sure we weren't missing any buttons required by the rules. We also decided to remove the indicator and wiper lever and instead put them on the steering wheel. Here is the buttons we have planned and what kind we wanted them to be (latched or momentary, push or rotary, etc):

- Left and right (push buttons, latched, possibly led for showing when on
- Hazard (push button, latched, LED)
- Wiper -four states (off, slow, fast, quick) (rotary, fluid when pressed)
- Headlight -four states (off, auto, parking light, low beam) (rotary)
- Cruise control -four states (off/on, set, increase, decrease) (push button, latched for on/off and set, momentary for increase and decrease)
- High beam and fog light (push button, latched, possibly led for showing when on)
- Headlight height adjust (thumbwheel)
- Radio volume (possibly one thumb wheel or just two momentary push buttons)
- Radio change channel (two push buttons, momentary)
- Horn (big push button, momentary)
- Extra buttons that doesn't do anything, so if needed the team can use one of those for anything they want

As seen on the rough sketch, we want to make the buttons be a little bit different from each other, so for some of them, like the horn, you would know without looking down which button you were pressing.

Since airbags are not legally required by the Australian road regulations, we decided therefor to forego them[2], because airbags are very dangerous if not installed correctly. In place of the airbag we were left with a sizeable cavity, with which we could fit all our electronics. We also had a discussion with the Mechanical Team and agreed that the steering weight could not exceed 5 kg, and locked in place the final outer dimensions of the wheel.

3.b Steering electrical design

We had a talk with some of the people from DTU Roadrunners, and they shared with us an example about how they had so much noise from an electric horn, that pressing the button interfered with the autonomous steering, causing the car to turn 90 degrees.
In our test circuit, noise was a considerable problem when bumping wires. Since we had to use the pins on our Arduino sparingly, we found a design for a circuit where we could use up to 4 buttons on 1 analog pin[3]. By using a resistor network as voltage dividers, each button press would feed a different voltage to the analog pin, so by detecting the voltage we can detect which button had been pressed. Therefore any noise would result in button presses being detected incorrectly.

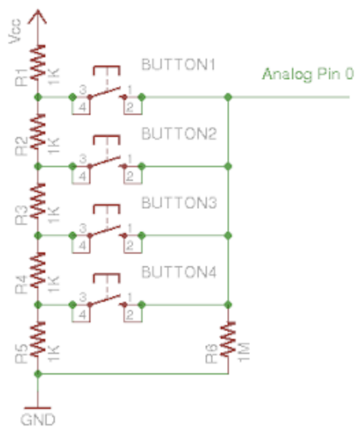

Figure 4: Electrical diagram of 4 buttons to 1 analog pin.

However, the noise from our test circuit can be removed if we make it into a PCB instead. But we only use that circuit as proof of concept, so we won't be making it into a PCB. We are also using a lot more buttons, of all different kinds, so we have to think about how to handle switch bouncing.

Switch bouncing is when the switch, while and after being pressed, bounces between being closed and open. "*When the switch is closed, the two contacts actually separate and reconnect, typically 10 to 100 times over a period of about 1ms.*"[4].

While the Arduino can somewhat deal with this, we can also make a hardware solution. This means that the software only will have to correct what is missed by the hardware solution.
We looked at the electrical diagrams for the eco car and from that we could tell they went with a R-C circuit to deal with the problem.

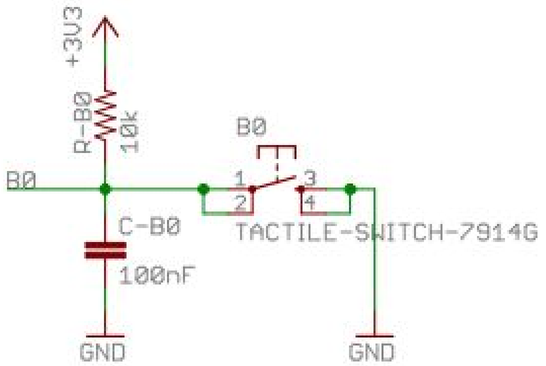

Figure 5: RC button circuit for the 2018 eco car steering wheel

However when it comes to streamlining this with multiple buttons instead of making each button their own circuit, it can complicated and tricky[5]. Instead we decided it would be better to use a IC debouncer, and we found that the MAX6818 is only around 5 dollars, and also removes noise from our signals and can do this with 8 inputs, while additionally only needing a 0.1uF capacitor to work[6].

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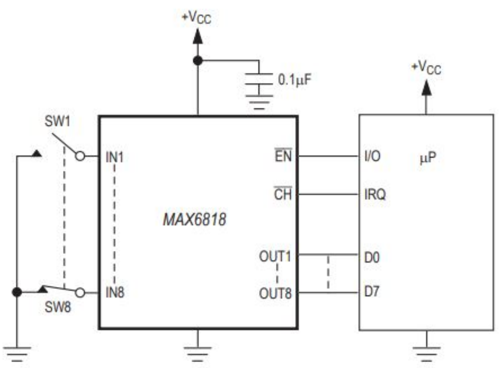

Figure 6: Electrical diagram of MAX6818 typical setup from[6]

3.c Display

Since some of the areas we would be judged on in the Bridgestone World Solar Challenge, would be Design Innovation and Comfort, we wanted to create a *General User Interface* (GUI) that reflected this. Our plan was to have a display built into the steering wheel. The eventual goal would be to use this display to feed the driver with all relevant telemetry data such as; Speed, battery percentage, predicted range, etc. In the grand scheme of things these functions were categorized in the nice to have section, and we tried to limit what we would use the screen for in our Introductory Project.

We decided that having buttons for controls with no visual indication was not practical, which is another area we would be judged on, therefore we would use the display to show which peripherals were activated and in which mode they currently were. This would include showing window wiper speed, headlight mode, indicator direction and etc.

Power consumption was an important aspect we had to take into consideration when choosing which type of screen to use. Originally we wanted to use an e-ink display. This display-type has a very low power consumption, since they don't require a backlight and only consume energy when updating what is being displayed. Even though these are some strong positives, they are still outweighed by the negatives.

As mentioned earlier e-ink displays don't have built-in back-lights, which could be a problem in low light settings. This problem could be mitigated by having built in LED's in the frame that holds the display in place, but it would also increase the work load in our already small time frame. Another issue with e-ink displays is that they are generally more expensive than other types of displays, and are not as readily available to us.

We ended up deciding it would be best to use a TFT LCD (*Thin-Film Transistor Liquid Crystal Display*). These display types have inbuilt touchscreen capabilities, which allow us to move some of the controls from physical buttons to touch inputs on the display. TFT displays are RGB, while E-ink displays are monochromatic, this would allow us to colour code our information, making it more legible to the driver of the vehicle.

TFT displays are also inherently easier to work with and they are more convenient to program, when using the UTFT library created by Henning Karlsen[7].

After finishing up with the buttons and overall design we began working on the display. After doing a bit of research where we compared pricing and screen sizes we decided to order a 3.2" 320x240 TFT LCD. After receiving the part we quickly ran into problems. First of all our display did not match the documentation available online. The pins of the module were mapped differently, which made the wiring process more challenging. The display requires about 34 pins that need to be wired, for complete functionality, so it was very impractical from a prototyping point of view. In all our attempts we would run into the same problem over and over again. The screen would be solid white with slight flickering. This meant that we had an communication issue between the Arduino and the display, we could turn on the back-light of the display, but we could not control the individual pixels.

We concluded that we must have a hardware compatibility issue, so we looked at different ways of fixing this. In our research we discovered a solution that would fix more than one of our problems. With our old display we had to individually connect each pin to our Arduino, this was very time consuming and never really worked. By using a module called a "TFT SHIELD", the display should become plug-n-play. However there are no shields available for 34-pin displays, we would instead need a 40-pin display. By the time we reached this conclusion, we did not have enough time to order the compatible parts and finish the programming, so we instead went with a new solution that used parts we already had available.

We ended up replacing our TFT LCD with a LCD type-character liquid crystal display (1602 LCD). This is a type of display that can show letters, numbers and characters in a 16x2 matrix. We were able to display window wiper speed, headlight strength and radio volume. For indicators we used a 8x8 LED dot matrix (MAX7219 MODULE), which would display an arrow to the corresponding direction. This solution was more of a proof of concept, it worked, but was not very practical.

3.d Regulations

All our work will be for nothing, if we continued with a design that was non-compliant with the regulations and rules of the competition, as this would result in disqualification. However, since the rules and regulations for the Bridgestone competition in 2021[8] were only published about a week before this paper was written, we had to rely on the old rule-set from 2019[9]. The rules and regulations were delayed due to the COVID-19 pandemic. After reading new rules, there does not seem to be any major changes. We based our design choices on the 2019 set, but we are prepared to comply with the current regulations.

Here are the rules that were relevant to us:

- Steering must be controlled by a steering wheel designed so that it cannot catch on clothing while driving or when the driver exits the solar car (2.19.1)
- It must be possible to flash the left and right direction indicator lamps simultaneously, as a hazard warning signal (2.24.11)
- The stop lamps must operate whenever driving is possible and the brakes are applied. (2.24.13)
- The daytime running lamps must operate whenever driving is possible (2.24.15)
- The following information must be provided to the driver always while driving: (2.26.1)
  - the speed of the solar car.
  - whether the direction indicators are operating
  - whether the hazard lights are operating
  - energy storage system warnings
  - electronic rear vision images (if fitted)
- Any cruise control function must automatically deactivate when the brake is operated, or the car is turned off. Cruise control must not resume automatically following a brake operation. (2.27.1)

So as we already described in the display section, we want to use the display to display all the things required be rule (2.26.1), as of right now the solar team doesn't plan on having a display other than on the steering wheel due to budgetary reasons.

4 Conclusion

Since we really didn't have a final product due to the limitations discussed in this paper, we can't evaluate that. However we can evaluate what we have done to try and reach our goals in the problem statement.

We have designed a steering wheel as seen in figure 1 and 3. To do so we had to communicate with the rest of ROAST so we could agree on what they wanted from us, and we could get some feedback for our design. We also researched steering wheel design, which included but was not limited to: display and switch types, electrical wiring, types of micro controllers and so on. We were able to settle on display type, an TFT LCD display; what kind of switches we have to have for our different buttons. And finally we look into the 2019 regulations to get an idea for what regulations we had to adhere to for the competition in 2021.

We ran into problems using our TFT Display, but were able to build a similar prototype using a 16x2 type-character LCD. This solution was not as practical, but it was a proof of concept that made us confident that our original plan would have been plausible.

We weren't able to look into any other of our priorities since we only end up with a very loose prototype. If given time we would like to build an actual prototype based on our final design (figure 3), and make a CAD and PCB design for this and test it out. We would also be able to test out a display since we now know that we have to use a 40-pin display, for our display to work optimally. We would also have liked to have looked at the energy efficiency, so that we wouldn't use energy that could have been used to power the motor.

Overall, we were able to prove that we could build a prototype as proof of concept, and that if given time and resources we could make a working steering wheel based on our more practical design.

5 References

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