Project Deliverable F: Prototype I and Customer Feedback

GNG 1103F – Engineering Design

Faculty of Engineering – University of Ottawa

Team 3 F01

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Introduction

The purpose of this document is to show the next step in the design process that our team is working on. The task at hand is to develop a modular product which will remove snow and ice from the campus sidewalks at the University of Ottawa. This would be a replacement for salt which causes severe damage to infrastructure and the environment.

This document goes over the beginning of the prototyping process. We have created two low fidelity prototypes. One is a physical prototype which demonstrates our design and its features. The second is a circuit diagram and an analysis of the circuit that will control the temperature of the mat, as well as some calculations on how stainless steel reacts when different current is passed through it.

Feedback

After our client meeting 2, the feedback on our design was positive. The client liked how simple the design is and that it was waterproof. However, one suggestion he brought up was creating the sidewalk on some sort of an incline to prevent water build up on top of the mat. We decided to take this feedback into account with future designs and prototyping. We also got some information on some more features the client is hoping to see. This includes a power switch, and an LED which indicates when the mat is on.

Prototyping Test Plan

Table 1 - Prototyping Test Plan

Test ID	Test Objective (Why)	Description of Prototype used and of Basic Test Method (What)	Description of Results to be Recorded and how these results will be used (How)	Estimated Test duration and planned start date (When)
1	Possible design methods for the tile connections	Physical, all-including design; experimental design	Record results based on observations (ease of production, effectiveness)	~1 hour
2	Support structure	Experimental design	Record results based on observations	~1 hour
3	Validity of concept	Experimental design	Record results based on observations	~1 hour
4	Heating concept requirements	Analytical Method	Estimate voltage that will be required to bring the temperature of wire to desired Temperature	~1 hour
5	Circuit Concept development	Analytical Method	Define proper circuit design for temperature control.	~1 hour

Stopping Criteria: All objectives complete, or the time limit is reached (2 days), or we run out of material.

Analytical Prototype

The Analytical prototype that was developed for this deliverable was in two main parts. The first part was to estimate the amount of heat that would be released from a stainless steel wire. The decision to use a stainless steel wire as opposed to a Nichrome wire was made since we have a need for extremely high temperatures that a Nichrome wire provides. Additionally, stainless steel is more accessible to us at the present time. To calculate the resistance, the resistivity of stainless steel was used. Using the power equation for a circuit element we can calculate how much voltage is required for a given length of steel wire to release a certain wattage. The process is shown below. The assumption is made that only approximately 50 percent of the power given to the wire would be dissipated as heat. This is conservative as it is likely more would be released.

$$Steel\,Wire\ \rightarrow L = 3.5\,m,\ d = 1.016\,mm$$
$$R = \rho L/A = 6.9E - 7(3.5)/(0.001016^2\pi/4) = 2.76\Omega$$
$$P = IV,\ I = V/R,\ P = \frac{V^2}{R}$$
$$P_5 = 25/2.76 = 9.05\,W\ (4.5\,W)$$
$$P_{12} = 144/2.76 = 52.2\,W(26.1\,W)$$

The above two values for power represent the two wattages that would be supplied by a 5 or 12 volt power supply. These are rough estimates and they give a better understanding of which voltage we should aim for. From this calculation 5 volts seems to be the better option. Not only because it is a low easily attainable voltage, but it is also safer due to the lower current in comparison to the two options. High currents can be unsafe which is why the 5 volts is going to be the voltage we aim for.

The current supplied to the wire will have to be shut off by the system periodically to keep the temperature constant. The below circuit diagram shows the design of a control circuit which would maintain a safe and desirable temperature. The process of designing this circuit has caused us to alter our BOM for an alternate set of circuit elements. This will be explored further in the next deliverable. The main function of the below circuit is an arduino which is connected to an opto isolator which allows the arduino to control the AC power flow in the heating wire. This is done with a soft switch made of a Triac. This is different from what was initially planned for the design as it was originally expected that the heating element would be controlled with a MOSFET. There will be a LED either connected to the arduino and will turn on whenever the arduino activates the heater, or a HV LED that will be connected in the AC circuit. This more expanded and detailed circuit drawing brought things to the team's attention. It has allowed us to consider the options for AC current and make changes to the design in further iterations of our product.

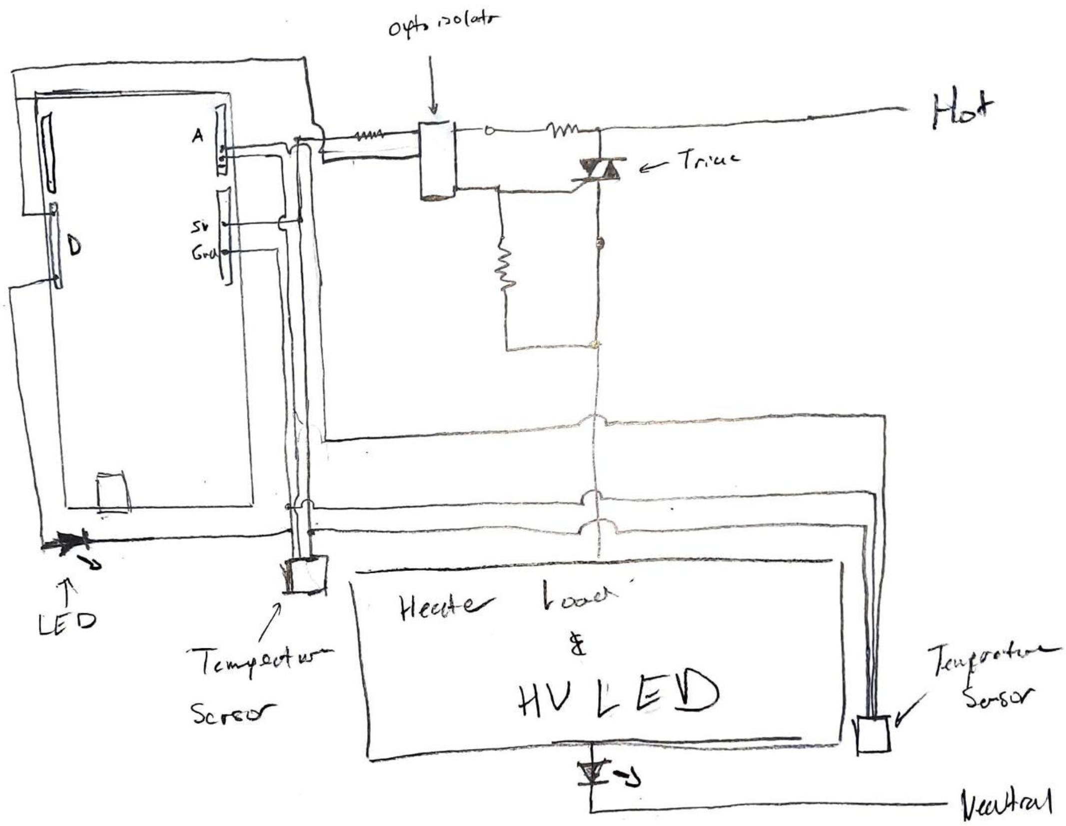

Figure 1. Circuit Diagram

Physical Design

The physical prototype for this deliverable is a cardboard replica of our design. It includes the connection “teeth” which are used to put the tiles together, the supports within the tile, and a dummy wire. As this is the first prototype of our design, we decided to create a model which allows us to see the relative proportions of the design. While creating more specialized prototypes is more effective in working towards the final product, this replica acts as a base for the design, and includes many of the major subsystems which need to be worked on.

The connection method used between tiles in our first prototype is a very simple design which uses many indented “teeth” lined up in a row to keep two tiles in place. Figure 2.2 shows an in-line view of the connectors. This design works well because it stops movement perpendicular to the direction of the mats, and is easy to recreate. On the other hand, it does little to stop movement in the parallel direction, meaning that these connections alone wouldn’t be enough to completely lock the tiles in place on their own.

The support structure, as shown in figure 2.1 and figure 2.4, seems like a promising concept. The purpose of these supports is to increase the maximum load of our design, and also provide a guide for where to place the wiring. A higher concentration of supports seems likely for our final design; since there seems to be no downsides to adding more supports, and would increase the maximum load of our design.

The overall concept of our design has become much clearer since creating our first prototype. Only two concerns have arisen from the current design, both related to the stability of the tiles. As mentioned before, the connectors on our final product will have to use a different design, preferably something more intricate. As seen in figure 2.3 and 2.4, holes line the sides of our design so that it can be bolted to the sidewalk. This first prototype has 3 holes on each side, but 2 holes on each side is likely more than enough. It’s important to keep in mind that many of these tiles are going to be placed in series, so each one should have a short setup time.

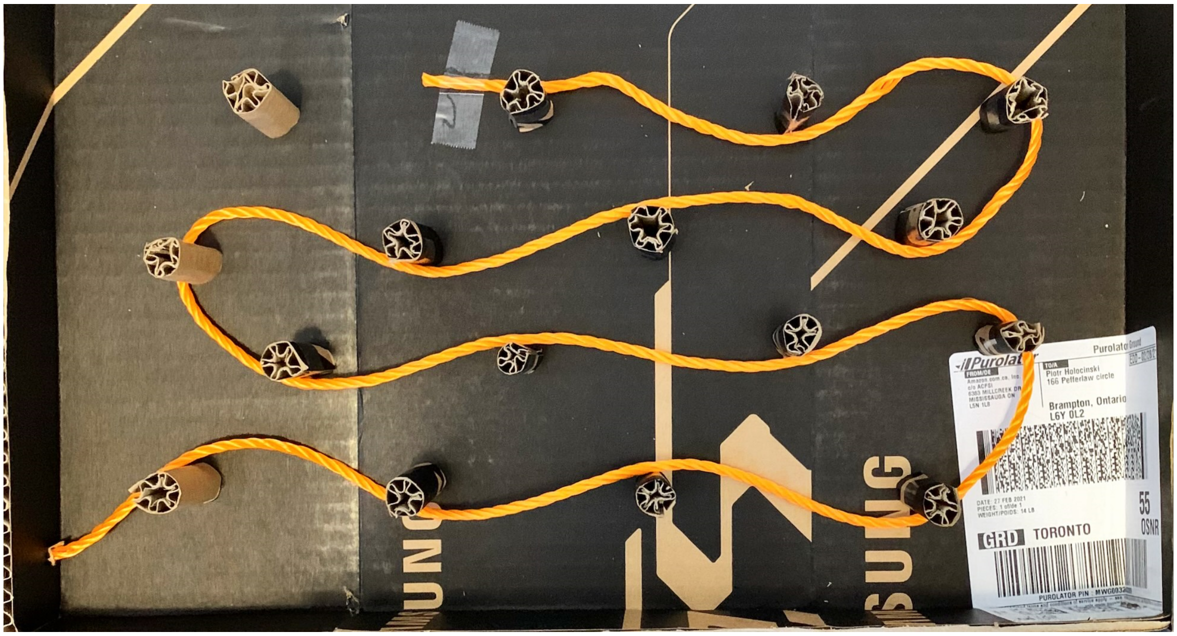

Figure 2.1 - support structure BEV

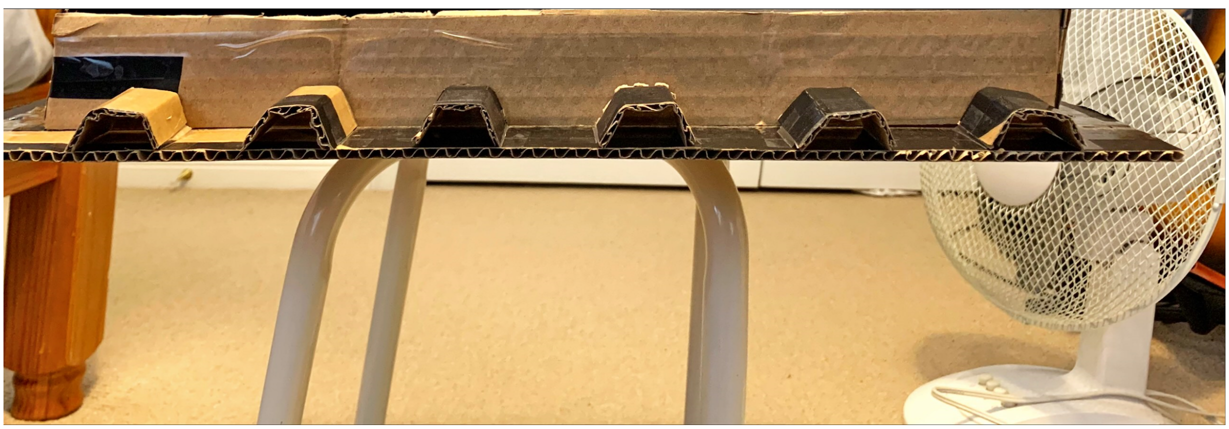

Figure 2.2 - Connecting Teeth

Figure 2.3 - Holes for Bolts to secure Mat

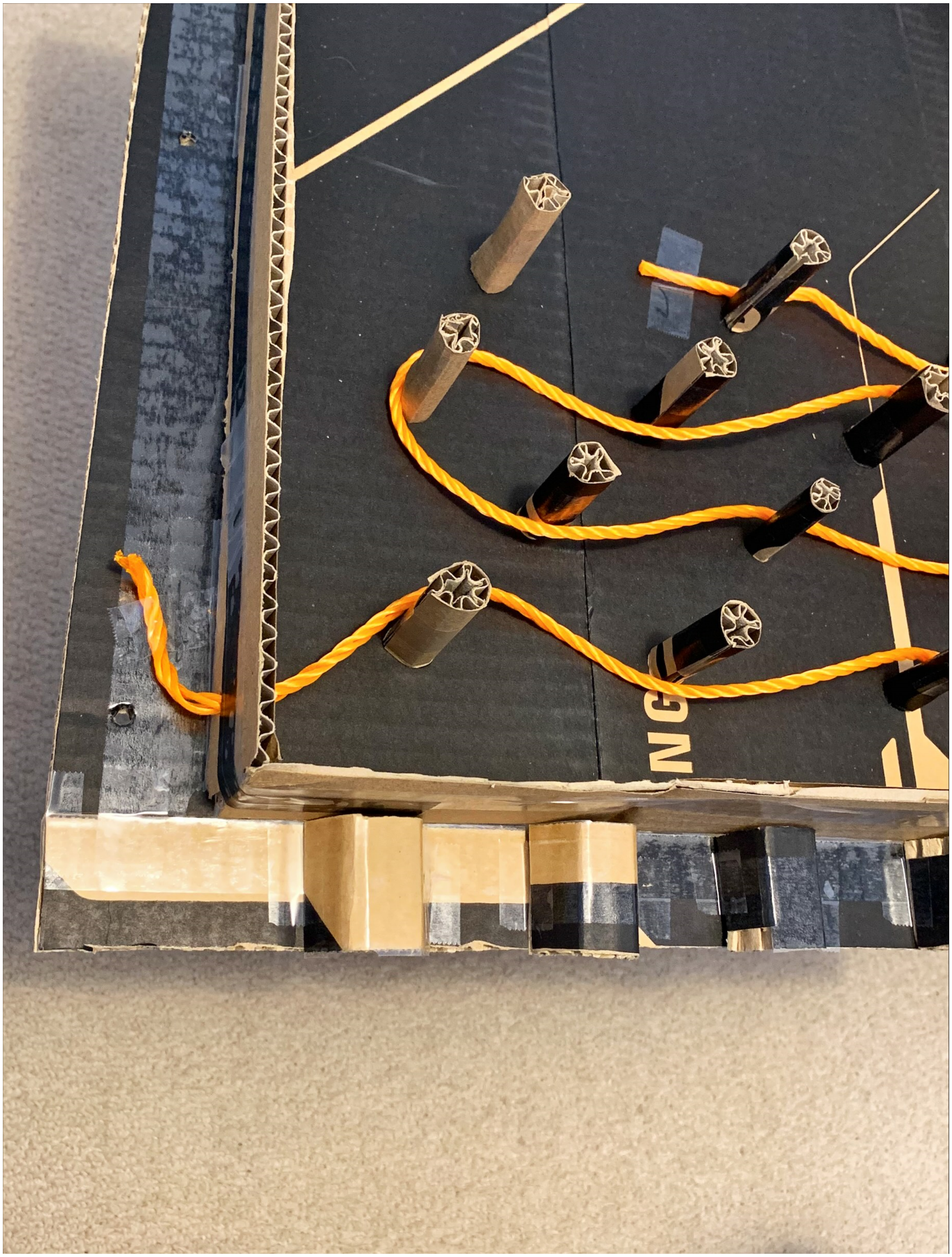

Figure 2.4- BEV of multiple systems

Figure 2.5 - Cover of Mat

Figure 2.6 - Full Mat

Wrike Task Board

The following link is a snapshot of our Wirke Task Board. It shows a gantt chart of our teams progress and subtasks to be completed. The snapshot highlights are goals for the next deliverables and subtasks to group members.

https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=euPK0OJ4Tm7Zkh3tbMoITiGqIlHgandJ%7CIE2DGNJSGE2TOLSTGE3A

Conclusion

The first prototype was created with the purpose of visualising our initial concept. Along with our physical design, an analytical design was created for the electronic components of our product. The circuit design provided further insight into the electrical requirement that our product will have. The second prototype will focus more heavily on the subsystem(s) of our design and developing them.