GNG1103

Design Project User and Product Manual

Power Cookies

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Introduction

Early in the winter semester of 2021 the class of GNG 1103 was approached to create a potential solution to the debatably excessive use of salt on the University of Ottawa's campus, or more specifically, the sidewalks during winter. Going into the project some major assumptions had to be made. The big three were that it regardless of the snow removal method chosen, it had to fit on a regular sized sidewalk, that whether a heated water or electrical method was chosen, the needed infrastructure would be available, and that it would not dampen the current infrastructure in place to aid in emergency evacuations and accessibility aides.

This document, the User Manual, has been made to aid the reader in understanding what exactly the Power Cookie Tiles are, how they are made, how they function, what went into conceptualizing and creating them, and how to install, use, and troubleshoot any issues that may arise while they are in use.

1. Overview

Road salt is used across Ontario to help provide traction and de-icing to sidewalks and streets. The economic and environmental impact of this practice builds up over time. Power Cookies aim to reduce the amount of rock salt used each year by providing a method to remove snow and ice from sidewalks.

The class of GNG 1103 was approached by the University of Ottawa to make an attempt at coming up with ways in which the university could provide clear sidewalks with heat. The main requirements, or user needs, were for the product to be compact, modular, relatively cost effective, more environmentally friendly then salt, possible to improve with ease in the future, and easy to install while maintaining a level of anti-theft protection.

Power cookies stand out in a market of similar products as they use an electrical heating method, are highly modular, they have a relatively low profile, and if a tile breaks, it is easy to tell which one broke. When dealing with a heating method for tiles or matts that melt snow and ice, a glycol based solution, or similar, can cause some environmental issues if one breaks and the glycol is released into the surrounding environment.

One of the big things Power Cookies try to do is be highly modular. There are three main aspects or subsystems that were chosen to allow for this level of modularity. Those were the side connections which provide the tiles an easy and effective way of connecting along each side, easy component access to allow for repairability and future upgrades, and replaceable rubber tops which allow for custom and new tops to be installed for things like emergency exits.

Some key features of the tiles are the heating coils made from nichrome wire (blue circle), the connectors between each tile (red circle), these can be seen if Figure 1, which passes power from one tile to the next while locking them together, the insulating material under each wire, and temperature sensor within the tiles. Some other main parts are the Arduino microcontroller and the main relay board.

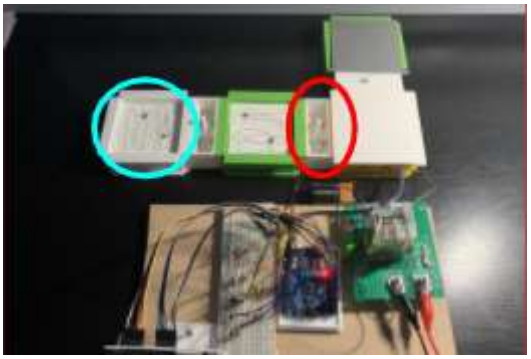


Figure 1: Final Prototype Design

The overall system works based on a temperature sensor in the tiles. It sits between the insulator and the top of the tile measuring the temperature of the air around it. When it detects the ambient air is below a certain temperature it will activate the heating system. Upon activation the wires will heat up until the temperature sensor reads the air temperature within the tile to be around 10-15 degrees Celsius (This can be changed through the code). Once the temperature has been reached, the wires will turn off until the activation temperature is reached again. This system will repeat until the tiles are turned off.

1.1 Cautions & Warnings

If a tile in the chain breaks it will be the only tile to not provide heat. All tiles after it should work as a result of the way they are powered. In the event of a tile not performing as it should, do not remove the tile while the system is powered. This could result in a shock, damage to the locking mechanisms, or the damaging of components.

2. Getting started

The system in general is very easy to put together as well as user friendly. The following headings will explain the proper steps clients should take when setting it up.

2.1 Set-up Considerations

For proper and safe installation, identify the location where power cookies will be installed. Connect the tiles together in your desired configuration. To anchor one tile to the next, simply retract the pins of the tile connector by rotating the actuator. Slide the connector in place joining the two tiles together, once the connector is centered, engage the pins by rotating the actuator 90 degrees using a flat head screwdriver as shown below. Once the tiles are connected the power supply assembly can be connected to the tiles. In a final product the power supply assembly would connect exactly as the tile connectors only slightly larger and with only one connecting side.

Step 1:

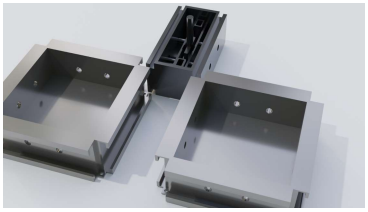


Figure 2: Tile Connecting Step 1

Step 2:

Figure 3: Tile Connecting Step 2

Step 3:

Figure 4: Tile Connecting Step 3

A standard 120V 15A outlet can handle a maximum of 5 power cookies, future plans are to allow a 120V to 240V adapter to allow up to 10 power cookies to connect to a 240V outlet if necessary. Once all tiles are in place it is possible to secure the tiles to the sidewalk beneath by drilling through the designated section of the tile and the sidewalk beneath.

2.2 User Access Consideration

When accessing the internal components of the system, one must ensure that the power supply is off. Next, open the cover of the tile you would like to access inorder to modify or fix any components. Afterwards, return the parts to their original position and restart the power supply.

2.3 System Organization & Navigation

In the current reiteration there is no actual system organisation/navigation. However, in a future design all the system components and features will be easily controlled off a portable app. The app can be accessed through any app store and be downloaded on a mobile phone. It will contain several sections that the user can navigate through to optimize the systems needs. There will be a section where the temperature ranges can be changed based on preference and physical climate. Additionally, it will contain a section where the client can monitor and see which tiles are engaged as well as the overall health of all tiles operating.

2.4 Terminating the System

In order to terminate the system completely from power, simply close the energy supply. However the electronic system will always be plugged in since it connects the arduino system. In case of a quick emergency termination the easiest way to shut off is to unplug from the main power source.

3. Using the System

The system that was built contains various sub-functions/sub-features that all put together the working tiles. The main function consists of the modularity and how easy it is to install the system. The next big function is the electric system that controls current flow for the heating process.

3.1 Modularity of Tiles - Easy Installation

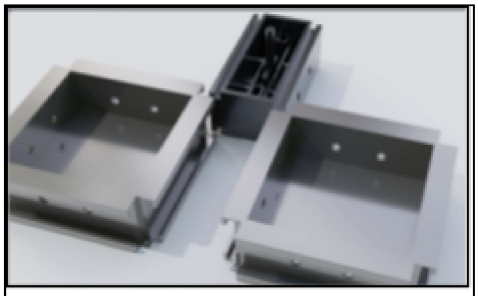


Figure 5: Female Male Installation

When it comes to the modularity of the system it is broken apart into two main modules. The first one consists of the larger female-female main tile and the male-male connectors. As seen in the image to the right there are two female tiles being connected to one male connector. The design allows for any pattern that a client wants, it can be arranged as a straight line or maybe even as a 3 by 3 formation. The female tile has 4 sides where a potential connector can be added to in order to create any shape that is desired. All tiles are also made with holes for installation into the concrete. A bolt is simply fed through the hole and then screwed into the concrete to hold the system in place. Additionally, the male connectors have two main functions when they are fully connected into its respective tile. They provide an electrical connection as well as a locking connection between two tiles. This happens when they are slid into the female tiles and the pins extend to lock them together.

3.2 Electric System - Power Output

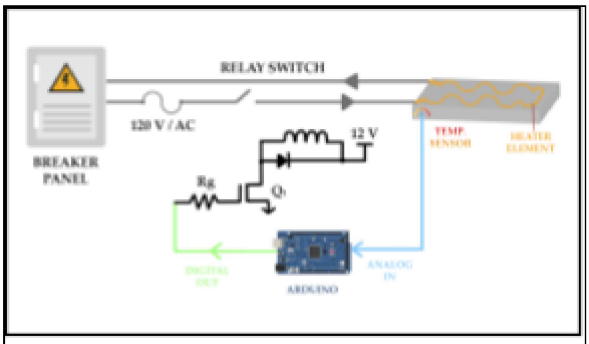


Figure 6: Electrical Diagram

The electrical system is also a main module that makes up the system and provides heat to all the tiles connected to it. The system is made up of an arduino that is connected to a temperature sensor and a relay board. The code in the arduino is based on the temperature readings which tell the board to either send current through the system or not. The code has a fluctuation pattern that tells the main board when to turn on and when to turn off. The power is then sent through all the tiles that are connected in parallel which then heat up.

4. Troubleshooting & Support

With any product, errors may occur, this section highlights possible issues and the best strategy to resolve them.

4.1 Mechanical/Physical

Tolerances of 3D printed parts are tight to ensure a snug fit, parts may need to be filed or sanded to ensure smoother use. An area of particular importance are the tracks that hold the tile to tile connector on the miniature tiles. Supports are required to properly print this track and must then be removed, residual pieces of supports may interfere with the connection. A flat head screwdriver, needle nose pliers, files and patience are all useful tools for removing supports.

4.2 Electrical

Test all components individually, to test if the tile is responsible connect a multimeter directly to both pins on all faces of the problematic tile as shown in Figure 7 below. Test the Tile-to-Tile connector by probing the left and right pins individually as shown in Figure 8 below.

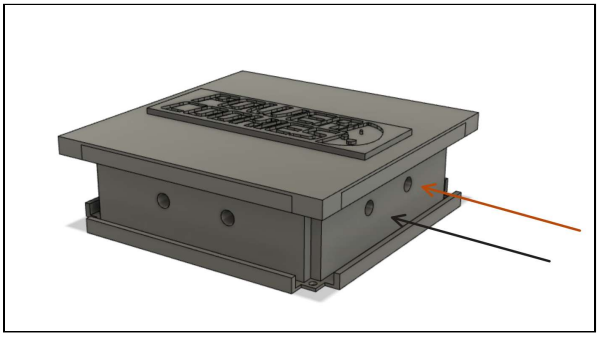


Figure 7: Tile Probing Location

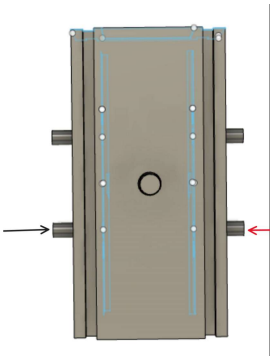


Figure 8: Tile-to-Tile Probing Location

Table 1: Solutions to Problems

Case Number	Case	Steps
Case 1	Power flows through tile through direct connection to the pins	Internal connections are in working order no further probing of the tile is necessary.
Case 2	Power does not flow through any of the pins	Remove cover from the tile, inspect the heating coil to verify that it is still intact, probe both ends of the heating coil with a multimeter to verify that power is flowing through
Case 3	Heating coil is damaged or not conducting power	The nichrome coil will need to be replaced. First unscrew the nut holding the nichrome coil. Remove the coil from the tile and follow instructions from section 5.1.3b to install the new coil.
Case 4	Heating coil is not damaged	Remove the nut holding the nichrome coil in place, remove the nichrome coil, carefully remove the first layer of fiber ceramic insulation. Inspect components for any loose or damaged wires or screws. Probe individual wires and connections to verify their integrity, the easiest solution is to solder loose connections and retest. If wires are overly damaged or the solder still doesn't resolve the issue, remove the damaged wire and replace it using the instructions in section 5.1.3b.
Case 5	Power does not flow through Tile-to-Tile connector	Inspect wires between pins, ensure the nut is secure and hold copper wire to the pin. Secure any loose wires to the pins. Remove any damaged or malfunctioning wires and replace them using instructions from section 5.1.3a.
Case 6	Power Flows through tile from direct connection and through Tile-to-Tile Connector	Pin is likely not fully connected to the tile. Best solution for the current model is to melt solder flux into the connecting hole of the tile to increase the strength of the connection.

4.3 Electronics/Coding

There are a few problems that can arise with the electronic component of the system. If the system is not heating at the desired temperature then a quick change in the range needs to be edited in the code. Additionally, the relay board may also have some trouble shooting to do. If current is not flowing through the board then the relay may be on the off setting. To fix this a wire should be connected from the power pin to the arduino in order to flip it on.

4.4 Maintenance

The main maintenance that should take place is a yearly check up on the internal heating resistivity wire. The nichrome wire can take a good amount of current through it, however doing a yearly check up can be beneficial in order to be safe. Simply take off the top plate of the tile to access the raw wire. If the wire has a different color than original it should be changed with a new one.

4.4 Support

In a future implementation of the product the app will have a specific function that can alert the maintenance crew if something suspicious happens. For instance, if the tiles are heating more that they are supposed too or if there is too much current flowing through the system. In this case, the app would have an immediate alert to inform staff on site.

5. Product Documentation

5.1 Subsystem 1 of prototype

5.1.1 BOM (Bill of Materials)

Table 2: Bill of Materials

Item	Cost (No Tax)	Cost (With Tax)
Temp Sensor	$10.40	$11.75
Nichrome Wire	$17.50	$19.78
LCD Screen	$10.40	$11.75
Screws,bolts,washers	$10.65	$12.03
Copper Wire	$6.25	$7.06
3D Printing	$29.55	$33.39
Relay Board	$0.00	$0.00
Arduino	$0.00	$0.00
Fiber Sheet	$0.00	$0.00
Power Supply	$0.00	$0.00
Total Cost	$95.77	

Table 3: Materials List

Item	Use	From Where
Temp Sensor	Detect Temperature	Gervais Electronics
Nichrome Wire (0.5mm dia)	Heating Wire	Amazon.ca
LCD Screen	Display Temperature	Gervais Electronics
Nickel Plated Electronic Screws,bolts,washers (2.5mm x 16mm)	Use for electrical connection	Gervais Electronics
Copper Wire (0.8mm dia)	Use for electrical connection	Home Depot
3D Printing	Main Tile Module	Makerlab/Alex's Printer
Relay Board	Connect arduino to main current	Pre-owned
Arduino	Micro-Controller	Pre-owned
Fiber Ceramic Insulation Sheet	Insulate Tile Module	Pre-owned
Power Supply	Provide power to system	Pre-owned
Bread Board	Connect Electronics	uOttawa
Male-Male/Male-Female Jumper Wires	Breadboard wiring	Makerlab

5.1.3 Instructions

The instructions provided in this section produce 2 miniature tiles and 1 Tile-to-Tile connector. Variations will be mentioned where applicable.

5.1.3a. Tile to Tile Connector:

Table 4: Tile to Tile Connector Parts List

Part Number	Part Name	Quantity/Length
1	Nickel Plated Electronic Screw (2.5mm x 16mm)	4
2	Nickel Plated Electronic Nut (2.5mm)	4
3	Copper Wire	2 x 6cm
4	Tile Connector Body *(STL)*	1
5	Actuator *(STL)*	1
6	Pin *(STL)*	2
7	Optional Cover *(STL)*	1
8	Optional Spacer *(STL)*	2

Assembly Procedure:

i. Print all required .stl files available on makerepo linked in Table 4 (recommended 100% infill for parts 6 and 7, 10-15% infill for parts 5, 8 and 9, 0.6mm printer nozzle for all parts).

ii. Gently thread screws through hollow pins on tile with screw head facing outward.

iii. Using needle nose pliers, loop both ends of copper wire to fit tightly around the free end of the screw.

iv. Place the formed loop over the free end of the screw, gently secure copper wire to the screw by fastening the nut in place. (Caution: pin is delicate; overtightening will cause print to split). Repeat for all screws. Both pins should now be connected to each other.

v. Push excess copper wire outward to form a “U” shape. Plates should be approximately 2.5cm apart. The “U” shape facilitates motion of the pins when installed.

vi. Optional: This step is not recommended in our prototype’s current design. Low tension rubber bands can be placed over the tabs in part 6. Intention of rubber bands is to automatically retract pins when the actuator is disengaged, in practice even low tension bands make extension of pins difficult. Thinner diameter copper wire could improve this feature but this has not been tested.

vii. This assembled component can now be placed in part 4 with pins fitting into corresponding holes in part 4.

viii. Part 5 may now be placed in the corresponding hole on the floor of part 4 with the longer end pointing upwards.

ix. Optional: This step is not recommended, in the prototype's current state spacers cause more interference than benefits. Spacers can be glued in their corresponding square holes in the floor of part 4. The intention of the spacer is to only allow the pins to retract as far as necessary. In practice spacers aren't necessary if step "vi" is skipped and may interfere with ease of operation.

x. Optional: Part 7 closes the completed assembly while still providing access to the actuator for operation. If step "vi" is skipped the pins must be manually retracted sealing the assembly is therefore not possible at this point.

NB. Individual copper wires cannot touch within the assembly, left and right pins **do not** connect to one another.

NBB. A multimeter can be used to verify connections. Current should pass through facing pins. No current should pass through diagonal or neighboring pins.

5.1.3b Tile

Table 5: Tile Parts List

Part Number	Part Name	Quantity/Length
1	Nickel Plated Electronic Screw (2.5mm x 16mm)	20
2	Nickel Plated Electronic Nut (2.5mm)	24
3	Nickel Plated Washer (2.5mm)	40
4	Copper Wire	8 x 10.5cm
5	Nichrome Wire	2 x 60cm
6	Fiber Ceramic Insulation	4 x apex 8cm x 8cm (cut to fit)
7	Solder	-
8	Hot Glue	-
9	Electrical tape	-
10	Tile *(STL)*	2
11	TIle Cover *(STL)*	2

i. Print part 8, (10% infill, 0.6mm nozzle, **85 degree** support angle recommended for better removal) remove supports from connecting rails of the tile. Needle nose pliers, flat head screwdriver and patience are recommended tools for this step.

ii. Measure and cut 4 squares from part 5 to fit tightly in the hollow portion of the printed tile.

iii. Using needle nose pliers, make a loop at both ends of each copper wire of the same diameter as the previous step.

iv. Using needle nose pliers, make one more loop roughly 2.5cm from the previous loop on 4 of the 8 copper wires only.

v. Place washers on each screw, then place the screws through all the loops you have just made. Place one more washer (sandwiching the copper wire between the two) and secure every screw with nuts.

vi. Bend the end screws of 6 of the 8 copper wires so the screw heads point outward. Bend all the midpoint screws so the screw tail points upward. The end screws of the final 2 copper wires should point in the same direction (for this prototype one tile serves as the main tile which connects to the power supply and electronics, for the main tile only the screw tails protrude from the tile allowing for easier connection).

vii. (by this step all screws, washers and copper wire should be used and 4 nuts should remain). Divide copper wires into pairs of one 3-screw wire and one 2-screw wire. This pair

should intersect at a right angle as close to the upward pointing screw as possible. Match the pair to any combination of holes within the tile which allows for this configuration as shown in Figure 9 below.

viii. Using the hot glue, fix the first pair in place with the screw heads in their corresponding holes,

ix. Solder the intersection between the pair and insulate the rest of the wire with electrical tape. Repeat steps “vii” to “ix” until all pairs are used. **Variation** for the main tile pairs with end screws in the same direction, make sure the screw tails protrude from both holes on the same tile face.

x. Align the fiber ceramic sheet with the hollow portion of the tile. Mark the position of the upward screw and pierce a hole in the fiber ceramic sheet for them.

xi. Make a loop in both ends of each nichrome wire. Coil the wire in a tight “S” shape. Place the looped ends over the ends of the screws protruding from the fiber ceramic sheet. Secure the nichrome to the screw using the final 4 remaining nuts.

xii. Place the Tile Cover over the tile to close the assembly.

5.1.3c Electronics

Table 6: Electronics Parts List

Part Number	Part Name	Quantity/Length
1	Breadboard	1
2	Temperature Sensor	1
3	LCD Screen	1
4	Custom Relay Board	1
5	Adjustable DC Power Supply (10V 8A)	1
6	Male-Male Jumper Wires	20
7	Male-Female Jumper Wires	15
8	Arduino UNO	1
9	9V Battery Snap Lock	1
10	9V Battery	1
11	Modular Heated Sidewalk Code	1
12	Copper Wire	2 x 10cm

i. Connect Components as shown in diagram below.

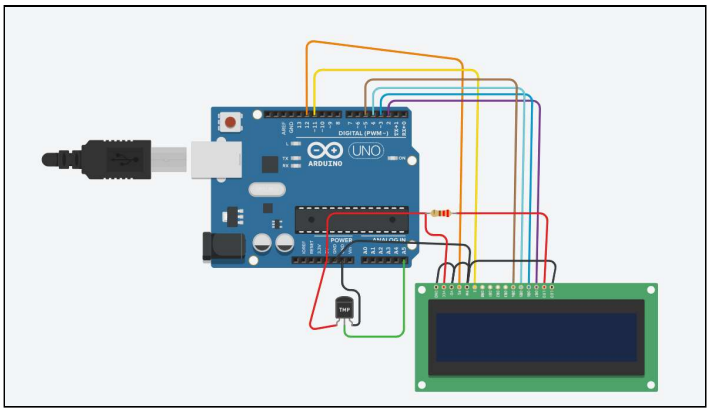


Figure 9: Tinkercad electronics diagram

ii. Download Modular Heated Sidewalk Code from MakerRepo and upload it to your arduino.

iii. The arduino is then powered by the 9V battery through the snap lock connectors.

iv. Connect the arduino to the custom relay board.

v. Positive and negative connections of the power supply are connected to one end of the relay board as shown in the Figure 10 below.

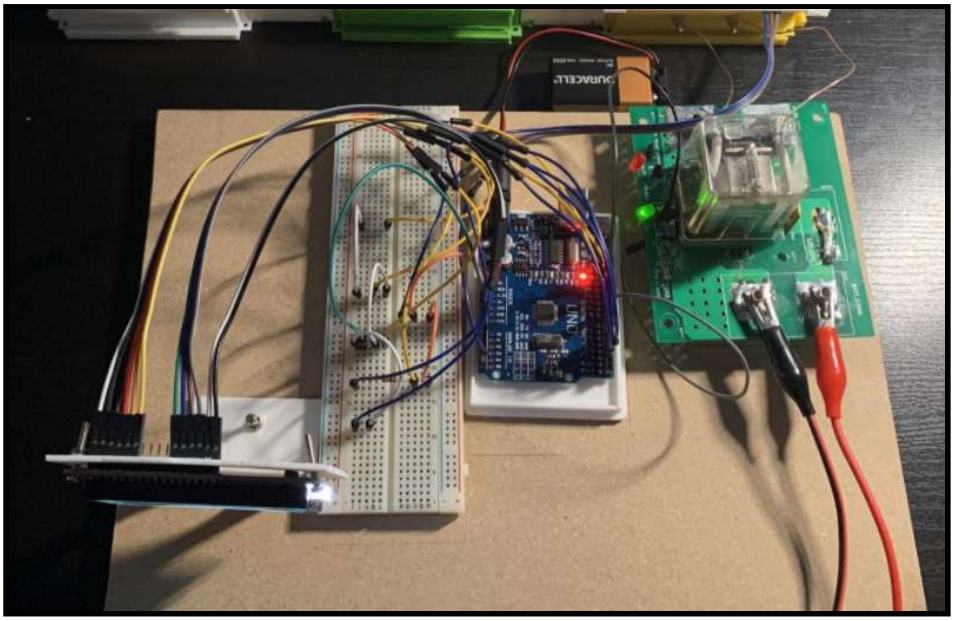
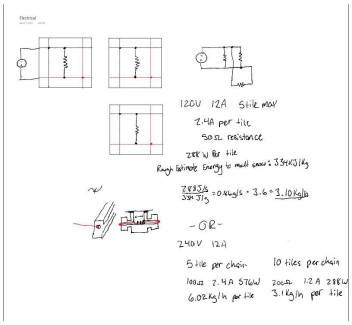
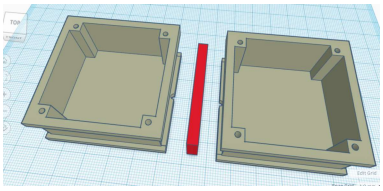
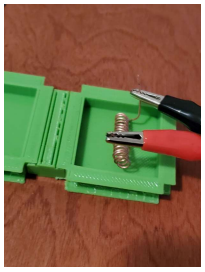
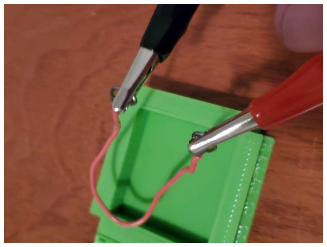


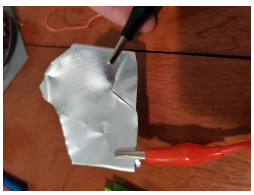
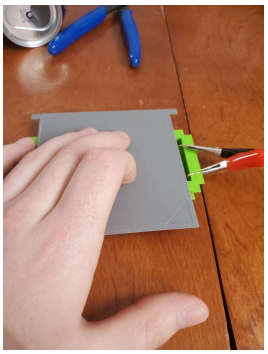
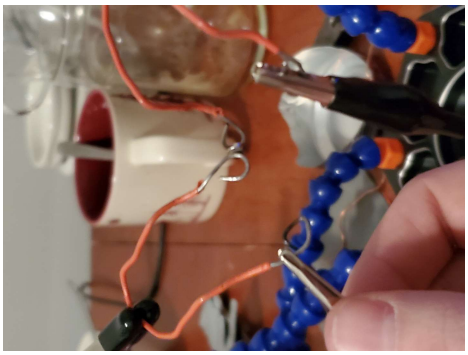
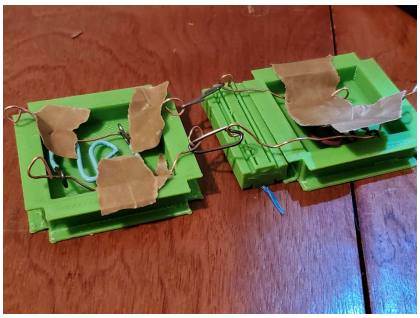
Figure 10: Aerial view of electronics, custom relay board connection

vi. Loop both ends of each copper wire, place one loop on the free side of the relay board the other loop will be secured to the screw tails protruding from the main tile assembled previously.

5.2 Testing & Validation

Table 7: Prototype I Creation

Test ID	Test Objective	Description of Prototype	How results were used
1	Produce a diagram that will be used as a template for the remainder of the project	Pictures were used as a guide for the project	A series of pictures which showed the connections and sample calculations that would be the building blocks for the final product 
2	Mating Performance	The tiles were 3D printed and slid into each other 	Once it was confirmed that they were able to slide into place the concept was considered proven 
3	Test different wire types for heating	Check to see how various wire types conducted electricity 	A device to measure temperature was unavailable, however it was warm to the touch. In the photo below a paperclip was used which had more resistance than the copper, it was found that it used less power in order to heat up 

4	Test whether or not a plate would be able to be heated?	Finding a material and attaching wires to it in order to heat it up.	On the left photo the aluminum can was heated quite easily, however it cooled just as fast. On the other hand, the second photo which has an abs plastic melted, however, the entire surface was warm.  
5	Test if the wires will work in series	Connected two wires in series together to ensure that the wires can transfer heat to each other.	 Due to the lack of a device with the capability of measuring temperature we checked to see if we could feel heat radiating from the wires. Smoke started coming off the wires quickly, this proved that the wires could be heated in series
6	Test if the the wires can be connected in parallel	Connect wires together in parallel to ensure that the wires can transfer heat to each other.	

			To build on the prior experiment the wires were heated in parallel. This proved to be a success with the wires being able to heat up the plates once tape was attached to them to keep them in place.

Table 8: Prototype II Creation

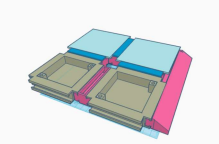
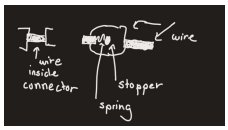
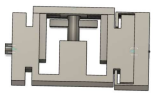
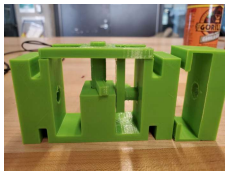
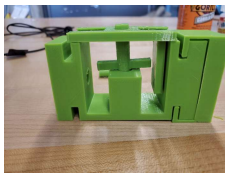
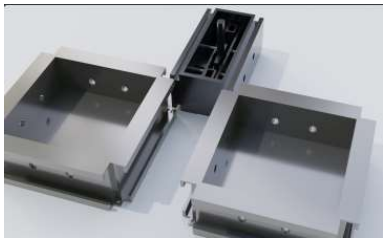
Test ID	Test Objective	Description of Prototyping	How results will be used
1	Create a revised 3D model of the tiled system(concept)		Results will be used to display the power of our modular design and how the tiles can be arranged in any format.
2	Electrical Tile-To-Tile Connection (Concept)		Results will be used to connect the tiles electrically which will lead to heating them up
3	Tile-To-Tile connection Physical Model (Concept)	 	This model was chosen for the ease of printing and assembling its components. Since the model was designed within a cross-section of one male-to-male connector it can easily be scaled up to be used in our final prototype.
4	Tile-To-Tile connection physical (Testing)	 	Testing proved that this design can connect tiles together reliably.

Table 9: Prototype III Creation

Test ID	Test Objective	Description of Prototype	How results will be used

1	Create and test the code the system will run	Using tinkerCAD, a system will be created to test and run the code to make sure the temperature sensor interacts with the heating components properly
		`void setup() {`
		`pinMode(8,OUTPUT);`
		`}`
		`void loop() {`
		`if ((temperature < 21) && (temperature > 19)){`
		`digitalWrite(8,LOW);`
		`delay(5000);`
		`} while (temperature < 18) {`
		`digitalWrite(8,HIGH);`
		`delay(5000);`
		`} else {`
		`digitalWrite(8,LOW);`
		`delay(250);`
		`}` (edited)
			The results of this test will be used to debug and edit the code to remove all the bugs that the system could have

2	Assemble the connections between at least two different tiles	Using small scale models and test pieces, the locking mechanism and the connector pins within will be tested to create the connections between tiles 	The results from this test will be used to determine how effective the connections are at both transferring the current and locking the tiles to each other
3	Testing the placement of the temperature sensor in different locations of the tile	Activate the tile and check where the coldest part within is. 	These results will be used to find the optimal placement of the sensor. This will allow the most accurate reading of when to turn the heating cycle on and off.

4	Run the wire through the tiles to find the best way to heat the max area of the tile	The nichrome wire will be run through the tile in different curvy/s-shape patterns 	These results will be used to figure out the best way to use the wire we have available (2ft per tile). This way the optimal pattern for heat distribution can be determined
5	Assemble a small scale version in its entirety	Using 3D printed components a small scale version will be fully assembled and tested to ensure that every part functions properly	Results from this test will be used to determine if anything can be improved or changed to produce the best possible product.

Each part of the prototyping took between one and two days, with multiple stages taking place at the same time. All together, the main sources of error in the prototyping process was the locking mechanism between the tiles and the code used to control the arduino. In order for the locking mechanism to be usable it had to be completely redesigned. Similarly, the code had to be redone for it to work as well. In the end, it culminated in a fully functioning prototype by the end of the semester.

6. Conclusions and Recommendations for Future Work

While the prototyping went well, a few problems occurred which allowed us to learn new skills and methods in an attempt to overcome them. The code used to control the arduino allowed us to not only learn coding but also debugging and fixing code which may not work. Similarly, the process of developing the locking mechanism taught us various skills. Most importantly it taught us failure analysis skills and the steps and methods to take after a prototype may refuse to work or function as intended. However, in the end, we were able to create a fully functioning prototype. While the prototype is functional, it is still not complete. Various modifications can be made to improve the prototype. One such method is to make additional modules for the prototype. A tile with an attachable rechargeable battery would prove to be useful in scenarios where a power outlet/source is too far for the tiles to connect to. The attachable battery could power the tiles that are far from a power outlet/source. Similarly, run-off ramps could be developed which can slide into the tiles and allow easy run-off for water from melted ice. Another method to control the run-off of water would be to create additional modules that are slightly raised towards one side. Another very important thing which could be implemented into the prototype would be the use of recycled materials. As one of the main goals of a heated modular sidewalk over the use of ice was to prevent environmental damage caused by ice, we found it necessary to implement some form of environmental friendly concept into our prototype. The initial thought was to use recycled/scrap materials whenever possible to develop the prototype. However, finding such material takes time and therefore it was not possible due to the limited time we had.

Due to a lack of time, the prototype developed was not the most optimal. Many things were abandoned which could have created a more efficient and user friendly prototype. One such thing was an app/wireless operation method to control the heated tiles. Using an app would allow the tiles to be turned on/off, the voltage and current flowing to the tiles could be controlled, and the temperature at which the tiles begin to run could also be changed. An app was thought of and the main concept was laid out but the app itself could not be developed.

7. Bibliography/Benchmarking

The Power Cookie tiles are made by those in Team 6. As a result, there's not much out there that was used as a direct reference. The aspects that would involve outside research come from the coding of the Arduino. The only other things that were referenced throughout the making of the Power Cookie tiles were the products listed in the benchmarking phase of the project. Below are a list of websites that were visited to aid with the code, and the benchmarking table made to get a baseline for this product.

Lady Ada "Using a temp sensor" learn.adafruit.com, https://learn.adafruit.com/tmp36-temperature-sensor/using-a-temp-sensor

imjeffparedes "Temperature Sensor With Arduino UNO", instructables.com, https://www.instructables.com/Temperature-Sensor-With-Arduino-UNO/

Professor Lakhani "Lab 4 - Arduino Process Control", uottawa.brightspace.com, https://uottawa.brightspace.com/d2l/le/content/209771/viewContent/3405412/View

Table 10 : Benchmarking

	Product 1	**Product 2**	**Product 3**	**Product 4**
Metric/Requirement/constraint	Snow Melting Heated Mats	Uline HeatTrack - Heated Entry Mat	Heated Snow Melting Walkway Mat	Warmup Snow Melting Cables
Cost ($)	571.99	779.00	180.00	$445.00
Dimensions (WxL) (in")	36 × 60	36 x 60	20 x 60	2016 x n/a
Weight (lb)	54	34	n/a	n/a
Thickness (in.)	Not given	0.5	0.5	3 - 5
Operating Temperature (°C)	-30	n/a	n/a	n/a
Heating Mode	Electric	Electric	Electric	Electric
Power Demand (W)	408	468	330	2000
Style (Mats, Tiles, etc…)	Roll up mat	Mats	Mats	Heated Cables
Material	Rubber	Thermoplastic Blend	Customized Thermoplastic	Fluoropolymer
Tile Temperature (°C)	7-10	54	54	n/a
Time to Heat (min)	5	10	other*	n/a

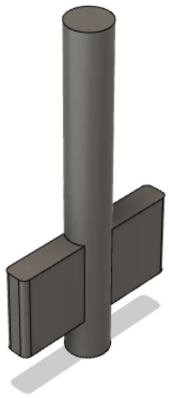
8. APPENDIX I: Design Files

Table 11: Referenced Documents

Document Name	Document Location and/or URL
Actuator	https://makerepo.com/BenjaminL/795.power-cookies
Cover	https://makerepo.com/BenjaminL/795.power-cookies
Logo	https://makerepo.com/BenjaminL/795.power-cookies
Pin	https://makerepo.com/BenjaminL/795.power-cookies
Spacer	https://makerepo.com/BenjaminL/795.power-cookies
Tile	https://makerepo.com/BenjaminL/795.power-cookies
Tile Connector Body	https://makerepo.com/BenjaminL/795.power-cookies
Tile Cover	https://makerepo.com/BenjaminL/795.power-cookies
Modular Heat Sidewalk Code	https://makerepo.com/BenjaminL/795.power-cookies

9. APPENDIX II: Component Images

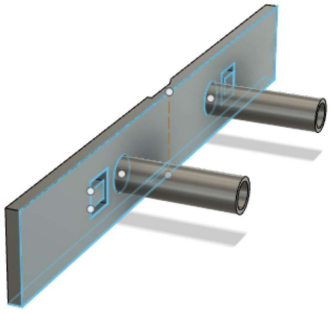
Actuator:



Cover:

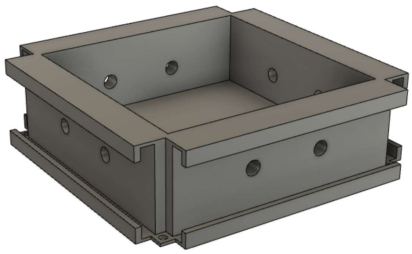
Logo:

Pin:

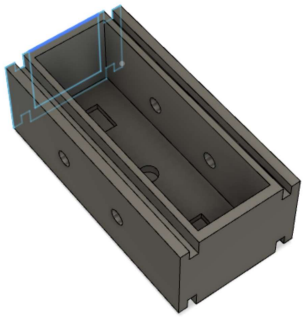


Spacer:

Tile:



Tile Connector Body:



Tile Cover