Homework 4 (Group Report): Engineering Principles

Due: Feb. 22 (Friday)

Section 1 – Summary of Assignments

Edmundo Anchondo – switches

David Evans – battery

Michael Placentra II – heating element

Joseph Vieitez – temperature control module and thermocouple

	Edmundo Anchondo	David Evans	Michael Placentra II	Joseph Vieitez
Percentage of effort towards this assignment	25%	25%	25%	25%

Section 2 – Summary of Research

Digital Temperature Control

This device should be easy to implement, at least for our prototype, because it is a standalone unit that accomplishes our desired functions. We require a DC controller than can interface with sensors (thermocouples) embedded in the plate. This will allow us to accurately regulate the surface temperature of the plate for safety as well as proper operation and performance. Ultimately, we would like a unit that will be adjustable within a certain range so that users could set the temperature level that they would like their food kept at.

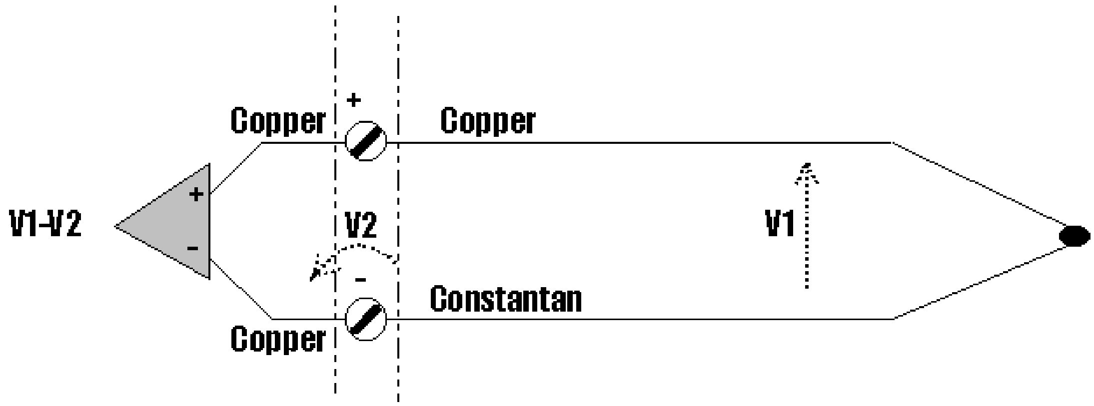
The controller could use on-off control as described by an article by the University of Exeter. This method is the simplest form of control and is used by most household thermostats. On-off control will probably be our best approach because it keeps the design simple and the cost of parts and manufacturing much lower than other methods. When the plate is cooler than the desired temperature, the controller will turn on the heating element. When the plate reaches or exceeds its desired temperature, the controller turns off the heating element. This can all be accomplished with a simple PID controller.

Thermocouple

Thermocouples work on the basis of a closed loop formed by dissimilar metals. A differing temperature creates a small current in the loop, and this can be measured and used to calculate a temperature. There needs to be a referenced known temperature. This could be useful if the desired result is to keep the plate a certain number of degrees above room temperature. The non-linear voltage as a function of temperature is calculated using the equation below, where ‘a’ is the Seebeck coefficient.

$$\Delta V = a * \Delta t$$

Since the terminal connection points of the thermocouple wire also form thermocouples, thermocouples operate using what is called “cold junction compensation.” The temperature is measured at the cold junction and the appropriate compensation is applied to the voltage reading.



There are several different types of thermocouples: J, K, T, E, R, S, and B. Each has different properties that can be evaluated in more detail at a later time.

Another important note about thermocouples is that installation is key to proper operation. There can be no breaks in the thermocouple insulation or the accuracy of the thermocouple will be compromised. There are some general rules of thumb for installing a thermocouple provided by IEEE. (http://www.ewh.ieee.org/soc/cpmt/tc7/ast1999/RS_TC/)

1. Never run thermocouple wire of thermocouple extension wire with any other type of wires.
2. Never run thermocouple wires of thermocouple extension wires near noise sources like transformers or motors.
3. Never pull very hard on the thermocouple wire or thermocouple extension wire. If it will not pull through the conduit fairly easily, find out why and fix it.
4. Never use regular copper wire anywhere in a thermocouple system.
5. Never cross the Copper and Constantan wires. Always connect Copper to Copper, and Constantan to Constantan.
6. Keep the number of splices to the absolute minimum. Make sure that the wire junction has good metal to metal contact of the same metal type as the target lead.
7. Keep the thermocouple run length as short as practically possible. If very long runs are required, consider a transmitter that changes the temperature to a 4-20 milliamp signal.
8. Never have more than 100 ohms worst case *maximum* in a thermocouple run. This is measured from the plus lead to the minus lead at the connection point of the measuring instrument.
9. Use the appropriate thermocouple or thermocouple extension wire insulation for the job.

10. Never connect one thermocouple to more than one measurement instrument.

Power Switch

This project requires a power supply that can be turned on and off easily. To solve this, we are looking into switches to utilize in our design. A basic switch has two electrical conductors that are brought into contact with each other through the motion of an actuating mechanism. A switch consists of two states, closed or open. When the switch is closed, the contacts of the circuit are touching, and can therefore have the current flow through it to provide power to the device; when the switch is open, there is no contact and therefore acts as the off position.

Classification of Switches

Switches may be classified in several different ways:

1. According to number of poles (SP, DP, 3P, etc.)
2. According to number of closed positions (Single-throw, double-throw)
3. Type of contact (Knife blade, butt-contact, mercury)
4. According to number of breaks (Single or double)
5. According to method of insulation (air-break, oil immersed)
6. According to method of operation [Operating Force (Manual, Magnetic, Motor), Mechanism (Lever, dial, drum, snap)]
7. According to speed of operation (quick-break, quick-make, slow-break)
8. According to enclosure (open, enclosed)
9. According to protection provided to circuits or equipment
10. Type of service (power switches, wiring switches, control switches, instrumental switches)

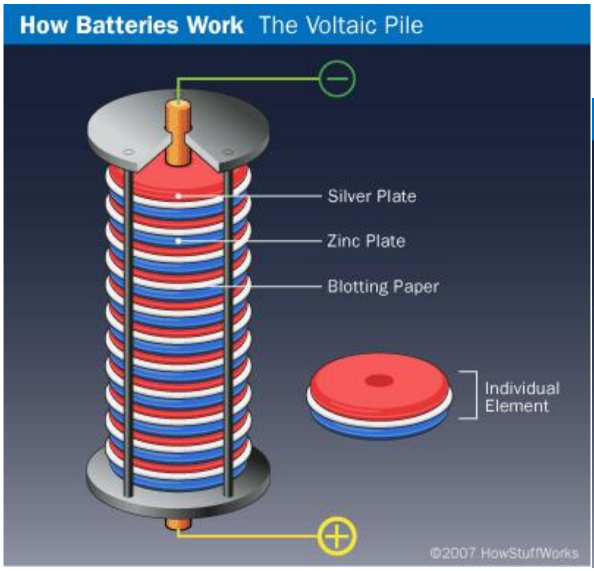
One switch type of interest is the toggle switch. A toggle switch works through manually moving the toggle between the on and off position. It can also have multiple positions, allowing for multiple functions of the switch. For our application, multiple positions on the switch could be a sort of “off, low, medium, and high” setting.

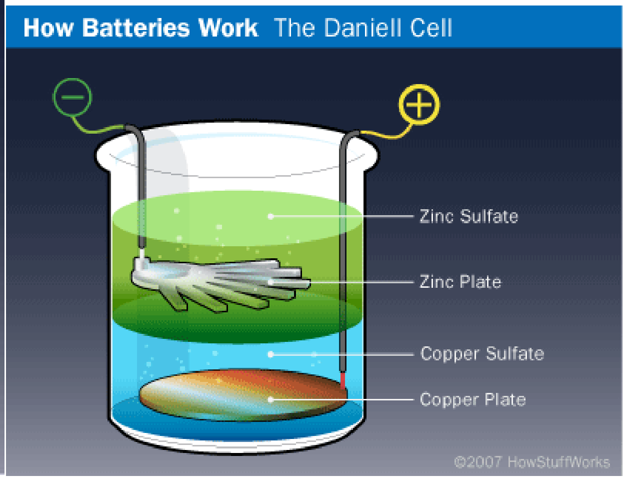
Another switch of interest is the rotary switch. They are used on devices that have two or more stages of operation. Rotary switches operate depending on the position of the switch. A rotary switch is designed to have a spindle, or rotor, that has terminals arranged around it. Each terminal allows a different amount of electricity to pass through it, allowing the appliance to perform differently. It is important for the switch to be in the exact position for proper functionality; if the switch rotor rotates too freely, the position may not be locked and move into another position, operating differently than the user expected. This is the reasoning behind rotary switches having a click mechanism, so that we know the rotor is in the desired position and is locked in place.

Batteries

For our prototype this battery should be strong enough to heat a plate, last a long time or be rechargeable, and be as small as possible. The highest priority is for this battery to be able to heat the plate quickly, efficiently, and not die out after just a couple weeks of use. The battery does not need to be rechargeable, but it would be an appealing feature for customers. Finally, the least priority would be the size of it. While it cannot be too bulky and take up too much space, the aforementioned requirements take precedence.

There are many types of batteries, but the basic idea is the same: when a device is connected to a battery, a reaction occurs that produces electrical energy. This is known as an electrochemical reaction. There are different layouts for batteries. The common layout such as on a AA battery would be one terminal with a plus, or positive, and the other with a minus, or negative. However, for a 9V battery, the terminals are situated next to each other at the top of the battery. For this project there are different battery types that could be used, but the biggest points in question are the size and if they should be rechargeable.





Rechargeable Batteries

For a battery to be rechargeable, the chemical changes that occur during the electrical discharge from the cell must be reversed when an opposite electrical potential is applied across the cell. Not all batteries are rechargeable due to the composition. For example, a rechargeable battery could be made up of Cd and NiOOH, which will discharge into $Cd(OH)_2$ and $Ni(OH)_2$, and then convert back to the first form. A primary battery on the other hand might work by converting (CF)n and Li metal to carbon and LiF. These batteries cannot be recharged because (CF)n is not reformed when a reverse potential is applied.

However, rechargeable batteries are not always cost effective. Low current draw devices do not warrant rechargeable batteries because these devices are changed so infrequently that the payback period for equivalent rechargeable batteries would be too long to justify the idea in the first place. Rechargeable batteries would make sense if there is a high current draw device that gets at least moderate use. The project would lean towards rechargeable batteries if a target is restaurants, as they would use these plates every single day.

9V Lithium Battery

These batteries are non-rechargeable. The lithium chemical will make the battery last for a long time with good storage ability and high power. These batteries are very commonly used in things such as smoke alarms, radios, and alarm clocks. Unlike the 9V lithium battery, the 9V lithium ion battery is rechargeable. These batteries typically range from around $6 to $9.

9V Lithium Ion Rechargeable Battery

These batteries are rechargeable and available in difference sizes and capacities. These batteries are very popular because of their high energy density ratio, their long lasting performance, they do not experience memory reduction, and their self-discharge rate is very slow when not in use.

Energizer Recharge 9V Batteries

For this product, which needs a long lasting life and high power, one of the best options would be the energizer recharge 9V battery. It is the best selling rechargeable battery in the world, and can be recharged hundreds of times. It is a bit more expensive, around $10-$14, but it would be worth it to somebody that would use these plates often.

Heating Element

The heating element will convert electrical current from the battery into heat, evenly heating the plate. This is by far what will draw the most power in the circuit, so efficiency is important. Durability is also important as it will probably not be replaceable. There are many different kinds of heating elements.

In general, the resistance of a heating element is calculated differently depending on whether it takes the form of tape or a round wire.

$$R = \frac{\rho l}{a}$$

For a wire,

$$a = \frac{\pi d^2}{4},$$

and for tape,

$$a = t(b - t) + 0.786t^2$$

where:

ρ is Electrical Resistivity (microhm.cm)

R is Element Resistance at 20oC (ohms)

d is Wire diameter (mm)

t is Tape thickness (mm)

b is Tape width (mm)

l is Tape or wire length (m)

a is Tape or wire cross-sectional area (mm2)

Screen-Printed

In the mid-90's, many companies started using screen-printed metal tracks in ceramic as heating elements in home appliances. A current across the metal tracks causes them to heat up, inductively heating the surrounding ceramic. This type of heating element is promising for our project because it would be convenient to simply print the heating element into the plates, which are already ceramic. It also has demonstrated success in home appliance applications such as kettles.

There are several sub-categories of screen-printed heating elements. Standard Resistance heaters have simple metal tracks which give off heat approximately linearly to voltage. They are manufactured by screen-printing a silver-based paste into wet ceramic, which is then rolled and cured in an oven. The formula for the current going through them is simply:

$$V = IR$$

High Temperature Thick Films are manufactured and operate on the same principals as Standard Resistance heaters, however they use different materials to operate at higher temperatures and with more wattage. In particular, the inks, substrates, and bonding material are different.

Positive Temperature Coefficient Heaters (PTC), a technology patented by Thermo LLC, are self-regulating in their heating properties, in that they automatically draw less wattage as they heat up.

Indium Tin Oxide heaters are designed to allow visible light to pass through unobstructed. The indium tin oxide compound is screen-printed into hot glass, which is then cooled to a solid form. A current is then passed along the tracks just as it is for other screen-printed heating elements.

Tubular

A tubular heating element acts as an elongated resistor formed into some shape to fit an application. Current is applied from one end of the tube to the other at one of several types of terminating ends. Terminating end types include "threaded stud, threaded bulk head, screw lug, quick disconnect spade, ceramic to metal hermetic, molded rubber lead, [and] conventional lead-wire terminal assembly" (Durex Industries).

The most common material in these elements is molybdenum disilicide. With this material, the element can operate at temperatures of up to (approximately) 1800°C. This is much higher than the operating temperature range of our project. Although it can certainly get hot enough, it will be too hard to control with precision in our much smaller operating range.

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