ECE 445 Project Proposal: Thermal Display

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1. Introduction

1.1. Objective

Display technologies have come to a point where innovation has somewhat been stunted. Since the first LCD displays came out, most displays after that (LED, OLED, etc.) looked essentially the same, but with improvements towards making images more realistic. For a center of innovation, the display technologies need to stand out more and therefore, professor Paul Kwiat asked us to build a thermal activated display for the IQUIST (Illinois Quantum Information Science and Technology Center) [1] office. **Thermally activated display technologies do not exist in a feasible form yet.** The ones that do exist, like the Thermochromic Display by 'Che-wei Wang' [2] don't look very appealing. Other companies such as LCR Hallcrest [3], H&H Graphics [4], etc. focus on building thermo-chromatic paper with printed designs or text underneath them.

Our solution is to build a thermochromic display that would use cut-outs of thermochromic paper as individual pixels. This would be a 3ftX1ft reconfigurable display monitor to display texts with high quality. We will use a grid of heating coils controlled from a micro-controller to heat individual pixels to make them change color as per our requirement.

1.2. Background

The University of Illinois at Urbana-Champaign is making a $15 million investment in the emerging area of quantum computing. This investment will see the formation of the Illinois Quantum Information Science and Technology Center (also known as IQUIST). The IQUIST Center is looking for a sign that they can display in their new building that is unique and visually appealing. The request for this display was originally made by professor Paul Kwiat. The idea is to incorporate engineering and physics concepts to a sign that will create a display that one cannot easily purchase online (such signs are not exciting or unique). The sign we will be designing will be the first of its kind and have a unique and colorful representation that will hopefully intrigue viewers into learning more about what IQUIST is all about. Our display must look as attractive and intriguing as possible.

Additionally, we plan to seek help from professor Paul Kwiat for understanding the theory and practical applications with thermochromic papers.

1.3. High-Level Requirements

- The display must be able to reconfigure the text within 10 seconds.
- The display must have a feedback mechanism when a user walks by in-front of it.
- The display must be able to display letters with clarity.

2. Design

2.1. Block Diagram

The design is made up of three main modules: Power Supply, Display Unit and Control Unit. The Power Supply ensures that each component receives adequate power. It comprises of two Voltage regulators, one for the control unit and one for the display unit. The Control Unit is made of a microcontroller, temperature sensors and proximity sensors. The microcontroller takes in the data from the sensors and then controls the heating circuits of the display to show the desired output. Finally, the display will be made up of two main components, a heating circuit grid, accompanied by a cooling system and a thermochromic paper grid. As the thermochromic material is temperature sensitive, it is important to monitor its temperature carefully for it to display the desired output. The heating circuit and the cut outs of the thermochromic paper aligned as pixels will ensure the clarity of text on the display. Because the heating circuit is accompanied by the cooling system (a thin metal sheet), the temperature would drop fast and the display would be able to reconfigure the text within 10 seconds. The proximity sensors will detect when a person is walking past the display and the microcontroller will then produce a feedback on the display accordingly.

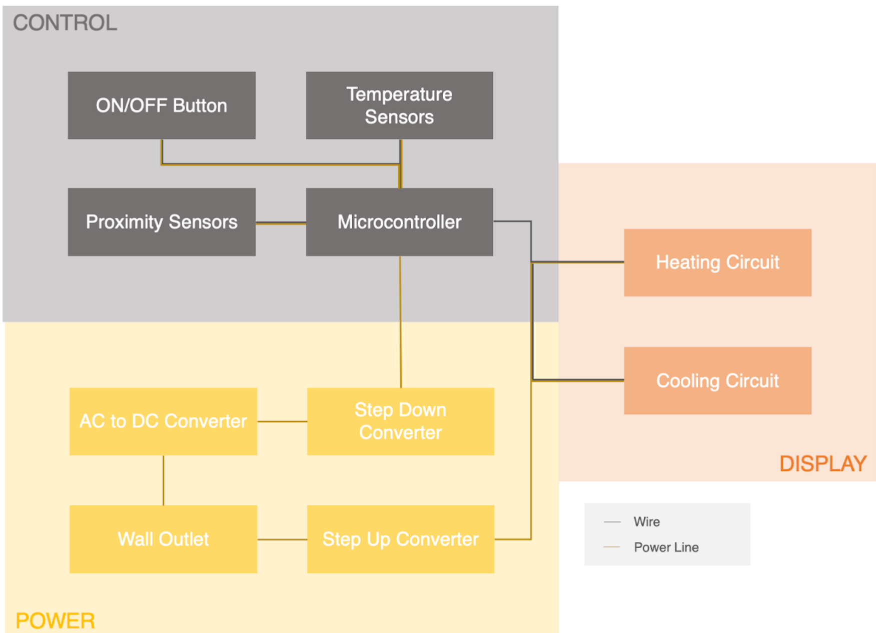

Figure 1. Block Diagram

2.1.1. Power Supply

A power supply is required to power the microcontroller, the sensors and the heating circuit. This will be taken from a wall outlet (120 V) and then will be converted to DC supply and passed through Step Down and Step up Convertors based on the equipment it will be powering in the system. The power supply block is responsible for supplying the appropriate current and voltage to the different components of the system. The microcontroller, sensors, and heating/cooling circuits operate at different combinations of voltage and current, and therefore must be routed their appropriate resources.

2.1.1.1. Wall Outlet

The entire system will be powered from a wall outlet. This will provide enough power to heat up the heating coils to a temperature of about 90-degree Fahrenheit and for the microcontroller and sensors to run indefinitely.

Requirement: Must provide > 2A at 120 V (the voltage supplied by the government in the U.S. power sockets.).

2.1.1.2. AC to DC Converter

The Microcontroller and other sensors work on DC current; not AC. Therefore, the AC to DC convertor will convert the AC current coming from the wall outlet to DC current which can be used by the different devices in the system.

Requirement: Must convert the AC current to DC current without changing the voltage.

2.1.2. Control Unit

The microcontroller will hold the logic for how the heating elements will operate to display the precise words we want to convey on the screen. The output of the microcontroller dictates which heating elements are supplied current, which is how each pixel of the sign is activated. The microcontroller takes input data from the proximity sensors in an open-loop design and alters the display in a manner that traces the path of an obstruction in front of the sign. For example, if a person steps in front of the right-most quarter of the screen, the proximity sensors on that side of the screen will pick up on this and send an analog signal to the microcontroller. The microcontroller responds to this signal by changing the color of that portion of the screen. This is the interactive function of the display design. The temperature sensors also feed into the microcontroller to regulate the temperature of the sign, ensuring that is does not overheat. For example, if the temperature sensors sense that the sign is heating up to a temperature that can potentially The microcontroller itself is activated with an ON/OFF push button.

2.1.2.1. Microcontroller

The microcontroller chip works on a 5V power supply. The Step-Down convertor will change the voltage of the incoming current from 120 V to 5V.

Requirement: Must step-down incoming voltage from 120V to 5V.

2.1.2.2. Proximity Sensors

An array of five Ultrasonic sensors will be used in order to know where the user is standing and be able to show a feedback to his movements in the display.

Requirement: the proximity sensors must be able to detect and locate the position of a user interacting with the display

2.1.2.3. Temperature Sensors

Four temperature sensors will be placed on the four sides of the display to be able to compute the average temperature of the thermochromic paper. The chosen sensors are

Resistance Temperature Detectors as they allow for the highest accuracy, of between 0.1 and 1ºC.

Requirement: the temperature sensors must be able to accurately measure the average temperature of the backplane of the thermochromic paper with an accuracy between 0.5º and 1ºC

2.1.2.4. On/Off Switch

A button to allow the user to switch off the display without having to unplug it from the supply, or in case there is an emergency such as overheating due to a short-circuit.

Requirement: the ON/OFF switch must be able to communicate with the microcontroller when it is actioned

2.1.3. Display Unit

The display block comprises of the heating elements, the cooling system and the thermochromic paper. Cut outs of the thermochromic paper are used as pixels for the display. Each cut-out will be placed on a thin metal plate (Copper or Aluminum). Since metals have high thermal conductivity, they heat up and cool down quickly. The heating elements will be arranged in the form of a grid. Each pixel will have its own heating element which would be in contact with the surface of the thin metal plate. When a specific pixel is to be lit up, the microcontroller will ensure that only the heating circuit for that pixel is receiving power through the ‘voltage regulator 2’ and this would heat up the metal plate. Within seconds, the metal plate would then transfer this heat energy to the thermochromic paper and the pixel would change color accordingly. When the pixel is to be shut off, the heating circuit would lose power and the metal plate would cool down, acting as a heat sink and cooling down the thermochromic paper. When the temperature reduces, the paper would deactivate.

2.1.3.1. Heating Circuit

The heating circuit will be made of a matrix of pixels. Each pixel will be made of a heating element that will be either NiChrome wire or a small sheet of copper and its control circuit. Different materials will be tested to see which one allows for the lowest power consumption.

2.1.3.2. Cooling Circuit

The cooling circuit will help dissipate the heat from the backplane of the thermochromic paper by the use of one heat sink in each corner, four in total.

2.2. Physical Design

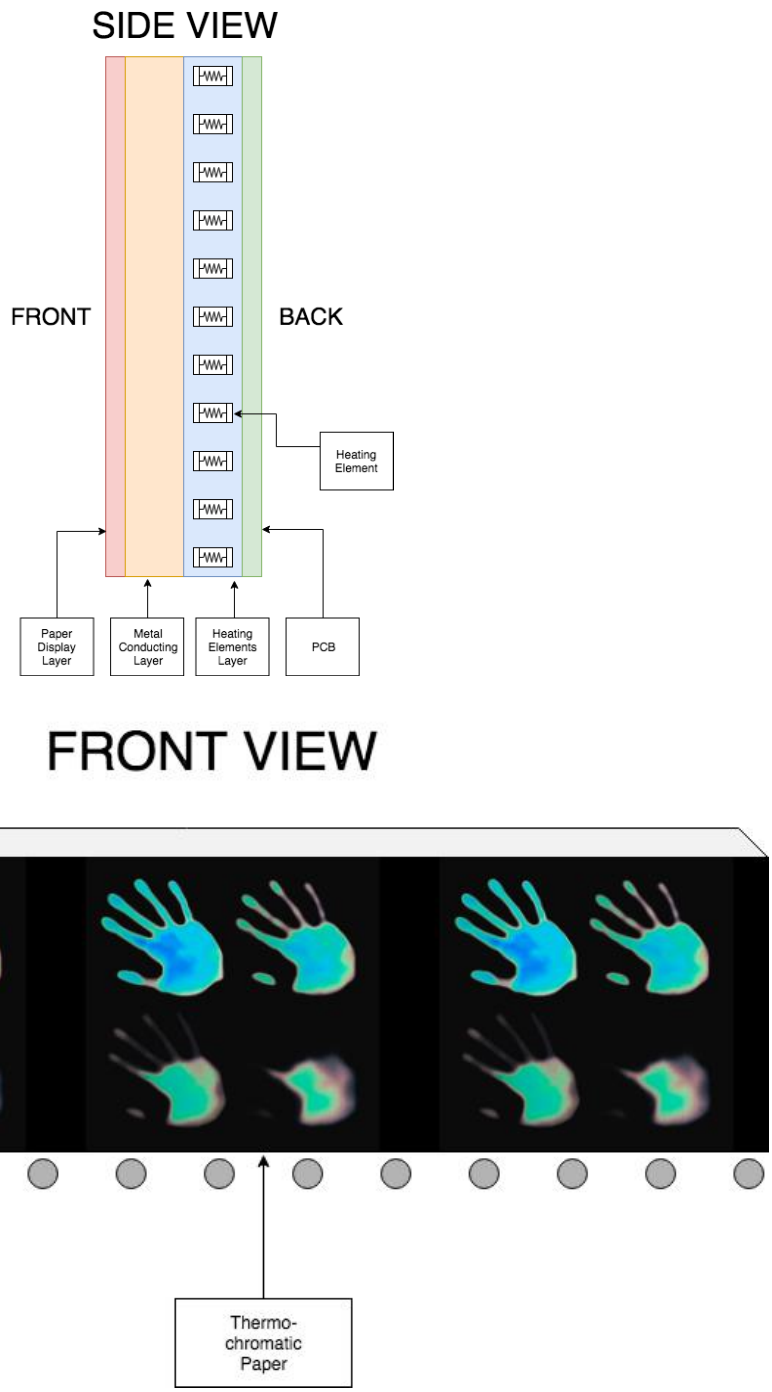

Figure 2. Physical Design

Our display will be layered. The top layer will be a thermo-chromatic paper material that changes colors based on a localized temperature. This paper will be in contact with the next layer, which is out heat sink layer. This layer provides a resource for heat to be absorbed to and reset the image on the display. Behind this layer will be the layer that contains our heating elements in a uniform matrix in order to make them configurable. Each of the heating elements will be attached to the PCB, which holds the heating elements in place, and acts as out final layer in the design.

2.3. Functional Overview

- Control Unit: The microcontroller will hold the logic for how the heating elements will operate to display the precise words we want to convey on the screen. The output of the microcontroller dictates which heating elements are supplied current, which is how each pixel of the sign is activated. The microcontroller takes input data from the proximity sensors in an open-loop design and alters the display in a manner that traces the path of an obstruction in front of the sign. For example, if a person steps in front of the right-most quarter of the screen, the proximity sensors on that side of the screen will pick up on this and send an analog signal to the microcontroller. The microcontroller responds to this signal by changing the color of that portion of the screen. This is the interactive function of the display design. The temperature sensors also feed into the microcontroller to regulate the temperature of the sign, ensuring that is does not overheat. For example, if the temperature sensors sense that the sign is heating up to a temperature that can potentially The microcontroller itself is activated with an ON/OFF push button.
- Power Supply: The power supply block is responsible for supplying the appropriate current and voltage to the different components of the system. The microcontroller, sensors, and heating/cooling circuits operate at different combinations of voltage and current, and therefore must be routed their appropriate resources.
- Display: The display block comprises of the heating elements, the cooling system and the thermochromic paper. Cut outs of the thermochromic paper are used as pixels for the display. Each cut-out will be placed on a thin metal plate (Copper or Aluminum). Since metals have high thermal conductivity, they heat up and cool down quickly. The heating elements will be arranged in the form of a grid. Each pixel will have its own heating element which would be in contact with the surface of the thin metal plate. When a specific pixel is to be lit up, the microcontroller will ensure that only the heating circuit for that pixel is receiving power and this would heat up the metal plate. Within seconds, the metal plate would then transfer this heat energy to the thermochromic paper and the pixel would change color accordingly. When the pixel is to be shut off, the heating circuit would lose power and the metal plate would cool down, acting as a heat sink and cooling down the thermochromic paper. When the temperature reduces, the paper would deactivate.

2.4. Risk Analysis

The block that poses the most risk is the Display Unit block of our design. We need to ensure that there is no possibility of the system overheating and/or driving too much current to different subsystems of the overall system. If a heating element gets too hot, it could create permanent damage to the thermo-chromatic display material. Additionally, the display must change the text on it as needed. This would require the thermochromic paper to cool down fast. The risk is that if the heat sink (metal plate) does not manage to absorb heat and dissipate it in time, it may cause problems by keeping the pixels activated that must be turned ‘off’ while displaying a certain text. This may cause the text appearing on the display to be unclear.

If the heat sink does not work fast enough, we would either try to change the metal to one with a higher thermal conductivity or use a form of metal press that would press a ‘cool’ metal plate onto the warm one in order to absorb the heat.

3. Ethics and Safety

This project poses a potential fire hazard if the temperatures rise to a dangerous level. We safeguard any potential harm to humans in 2 layers of protection. The first layer of protection is provided by temperature sensors that measure the overall temperature of the sign. If this fails, the next layer of protection would be to implement overcurrent protection on the power supply. If the wrong combination of voltage/current is supplied to a component, it could potentially fry that component. We do not want anything to release any smoke or catch fire, so we will be safeguarding against this by regulating the temperature of display and by placing overcurrent protection on the power supply.

Electrical Safety can be a concern since the power is being supplied directly from the wall outlet, which provides a voltage of 120V. The safety will be maintained by using voltage regulators and a fuse at different points in each unit of the system. This would not only ensure that the voltage remains constant, but also that the temperature doesn’t rise high enough to damage the equipment.

Mechanical Safety won’t be much of a concern since the project does not use moving parts. However, users may touch the heating coils by mistake while trying to view the project. Therefore, we will provide a casing for the entire display to hide the heating coils from sight and avoid human contact.

Ethically speaking, the project does not cause any violations. Since we do not ask for any personal data or intrude into anyone’s privacy, the project would not have any ethical concerns. As the IEEE Code of Ethics state [5], we hold paramount the safety, health, and welfare of the public.

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References

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