Thermochromic Paper Display

Inspired by Spring 2019 Project 36, "Thermal Display"

By

Team 21

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1. Introduction

1.1 Objective

Society has become dependent on the growth of technology and its applications in our everyday lives. However, we tend to be complacent when problems have been solved and we don't strive for innovation anymore. In terms of the current state of modern displays, we predominantly use LCDs for all our displays from computers to televisions. After speaking to a number of art college students, a need from some of our peers was to have a method of electronic expression outside of the norm. Curiously, we began to think what other ways outside of the LCD can we display images on a platform that is similar yet fundamentally different from the former method.

We decided to create a new form of display based on a previous team's project "Thermal Display". Our project would involve using thermal paper but rather than have a coil heat it to form an image, we would be using a high-powered laser to heat the paper. Essentially, we will be dividing the paper into pixels and warming it to the desired color by scanning a laser across the paper and changing the intensity of the laser. This method hence will give way to a new means of display and projecting desired images. Figure 1 demonstrates the image of a handprint formed on thermal paper. The laser based system here will not have as high a resolution, however grayscale images will appear similarly to the hand shown (in Figure 1) [1].
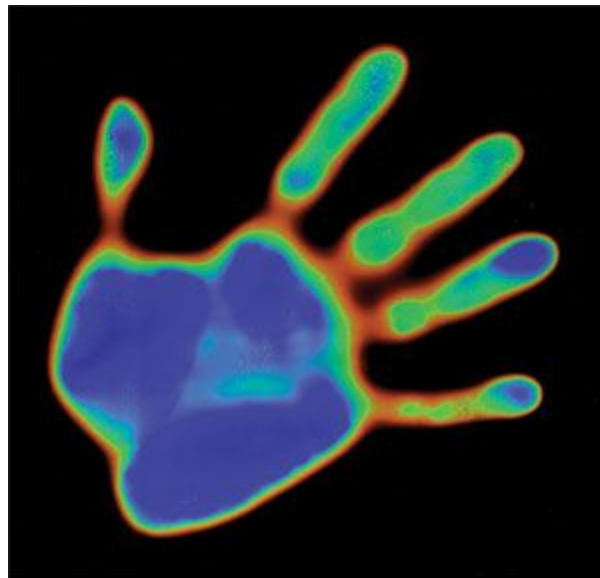

Figure 1: Handprint Formed on Thermochromic Paper

1.2 Background

The University of Illinois previously made a multi-million dollar investment in quantum computing [2]. The investment led to the creation of the Illinois Quantum Information Science and Technology Center (IQUIST). Professor Paul Kwiat made a request for a sign that could be shown in the new center and was original yet unique in its own way. It had the intention to be visually appealing while using the general concepts of physics. With this in mind, we set off to learn more about the previous group's ideologies and decided to use these as standards when creating and researching a new type of display to build, thus essentially mirroring the influence and necessity behind finding an adequate solution.

We decided to set apart our project from the previous group's project through the use of lasers instead of heating coils. We predict that we will be able to have a more accurate form of heating the thermal paper to produce the entire image. Also in regards to the background setup, the circuitry of the project will also differ. We will be implementing motors and motor controllers in combination with the lasers to assist in the project.

1.3 Visual Aid
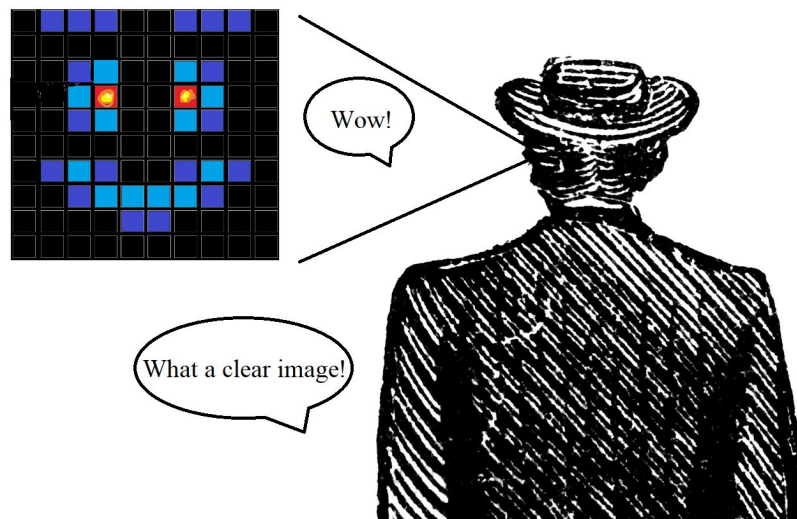
Figure 2: A Visual Aid

Figure 2 illustrates the proposed screen in use with a more accurate resolution. From the user perspective, the device will function like a standard display: a liquid crystal sheet which displays a 2D image on its front face. The image above shows a simple smiley face in 10 pixel by 10 pixel resolution however the final display will have roughly four times more pixels and will be capable of more complex images.

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1.4 High-level Requirements

- The ability to display monochromatic, 25 pixel by 25 pixel images or letters on a roughly 6 in by 6 in square screen within 1 minute.

- The laser must have a maximum beam width of 2 mm to account for pixel sizing.

- Power consumption should be similar to that of a modern monitor (approximately 100 kWh/year).

2. Design

2.1 Physical Design

Figure 3: Expanded View of Display Components
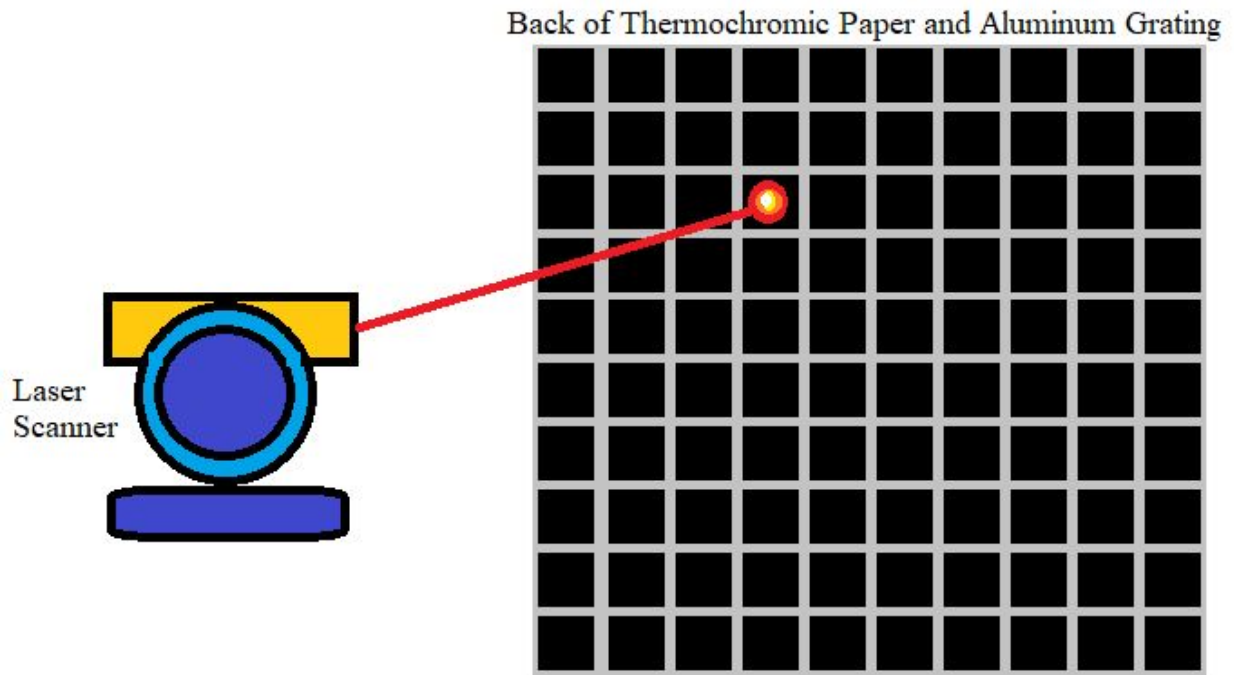
Pictured above in Figure 3 is a simple render featuring the physical aspects of our design. The structure will include a layer of thermochromic paper mounted against an aluminum-mesh heat sink and a laser mount housed a short distance away. The laser mount includes the high-powered laser for heating, two motors and a gear system to aim the laser at the appropriate pixel.
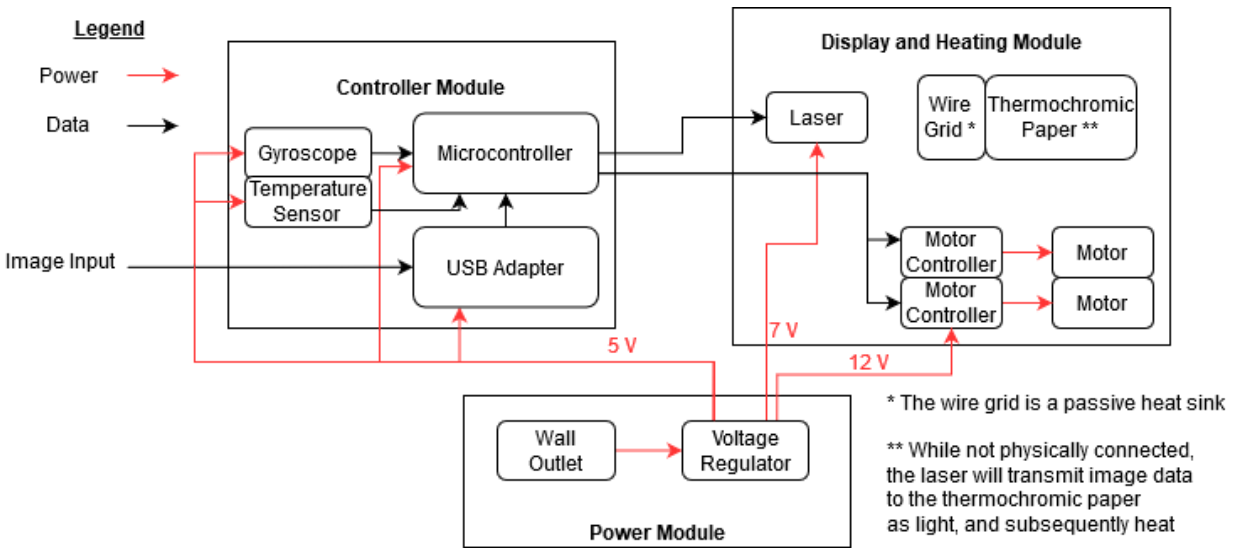
2.2 Block Diagram

Figure 4: A High-Level Function Block Diagram

As shown in Figure 4, our project requires three modules for successful operation: a power module, a controller module, and a display and heating module. The power supply ensures that the system can be powered continuously with stable 5 V, 7 V and 12 V sources for the respective module voltage requirements. The controller module consists of a microcontroller (ATMega328P), and gyroscope for precise control of the laser. The microcontroller takes in data from the sensors and controls the motors and heating of the laser in creating the final image. The display and heating module is made up of two motors and their controllers, the laser directed at specific areas on the paper and the wire mesh that will form the pixel grid by constraining the heat to a certain area per pixel, it would also act as a heat sink to prevent burning the paper. Each motor in this module controls a single axis to angle the laser appropriately.

2.3 Functional Overview & Block Requirements

Display and Heating Module

The display and heating module is responsible for generating and rendering the final image. It consists of a laser, its motor-controlled mount, a sheet of thermochromic paper and a passive aluminum grid which acts as a heat sink. By using the laser to heat up the back of the thermochromic paper an image will be formed on the front.

Thermochromic Paper

The thermochromic paper consists of a single liquid crystal paper sheet that will be heated by the laser and will change color as heat is generated by laser absorption to create the final image. Generally, the system functions by converting light from the laser into heat which in turn changes the color of the paper for a temperature range of 30 ℃ to 35 ℃. By modulating the intensity of the laser, the amount of heat transferred to the paper can be controlled. When the laser stops heating the paper it will cool down via the aluminum wire grid. Specifically, heating the liquid crystal sheet realigns the crystals at different angles which results in different colors being reflected from the sheet as shown in Figure 5. When the paper is outside its temperature operation range it remains black. For ours, between 30 ℃ to 35 ℃, it transitions colors from red to yellow to blue. As the temperature changes, the liquid crystal assumes a different molecular organization. As a result, the interaction with light changes and causes the color to change. There are different temperature ranges for different specific paper samples so we will need to calibrate ours via testing as shown in Figure 6. But roughly it should start changing to red at 30 ℃, green at 31 ℃, and blue at 35 ℃.

While not physically attached to the laser, the laser will print an image onto the thermochromic paper via heat. This heat will be managed by the wire mesh which will focus the heat on the specific pixel and absorb excess heat.
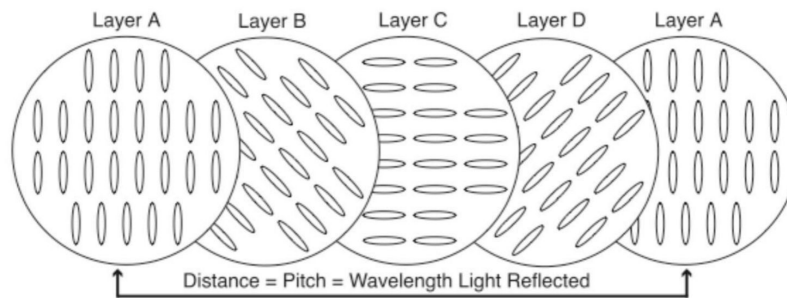
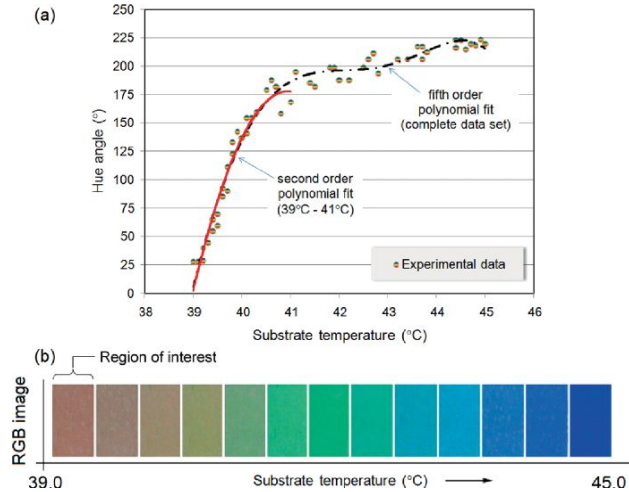**Figure 5:** Molecular Layers of Thermochromic Sheet

Figure 6: Calibration Curve for Desired Color Range of Paper Material

Table 1. Thermochromic Paper Requirements and Verifications

Requirements	Verifications
1. The thermochromic paper must begin to change color at 30 ℃ and have completely changed color at 35 ℃.	A. We will have a temperature sensor to constantly test and ensure that it changes color at the right temperature range.
2. The thermochromic paper must not change color at room temperature.	A. Visual test when the laser is turned off.

Wire Grid

The aluminum wire grid is a passive feature of the design which is mounted directly against the back of the thermochromic paper by glue or other bonding agent. This unit consists of a square grid made of aluminum which acts as a heat sink and enforces pixel borders as described in verification in Table 2. Since the 6 in by 6 in square will be split into a 25 pixel by 25 pixel array, each pixel is roughly 6 mm by 6 mm. To promote quick heat dissipation the aluminum will take up all but a 3 mm by 3 mm square centered at each pixel, i.e. the grid is made of 4 mm thick wire which forms 6 mm by 6 mm squares.

Table 2. Wire Grid Requirements and Verifications

Requirements	Verifications
1. The grid transfers heat evenly onto the surface of the thermochromic paper to keep each pixel at its current temperature and above 30 ℃ to keep it from turning back to black.	A. Using a temperature sensor along the edge of the grid to ensure the grid is distributing the heat to the entire paper at a certain temperature when the laser is turned on.
2. Wire grids should also dissipate the heat quickly when the laser is not heating up.	A. Timing how long the grid takes to go back to room temperature when the laser is turned off.
3. Square cut out space of 3 mm by 3 mm to allow the laser to directly heat up paper to the desired temperature for each pixel color.	A. Measuring each square using a screw gauge after manufacturing.
4. Grid should be able to withstand being heated by the laser beam i.e. thermal heat capacity.	A. Testing the heat capacity of the grid when the laser is heating for duration it takes to create a full image.

Motor and Motor Controllers

The laser mount and guidance consists of the motors, motor controllers and gyroscope depicted in Figure 7. This unit is controlled by signals from the microprocessor and in turn aims the laser at the desired pixel. The motion of the laser will vary based on how much energy or time of heating is required to get the desired effect or color before proceeding to the next pixel. The speed of the laser is only limited by the speed of the motors but this will not be a problem as most standard motors move very fast and we can turn on or off the laser in states where the required motion speed can be met to allow the motion before turning the laser back on to continue. Further steps to verify this in Table 3. The laser will be placed on one motor which is attached to the other. The base motor would be set up to turn the upper system parallel to the base (horizontally) and the second motor would then be stacked on it and have the laser connected perpendicularly to its rotational axis which controls the vertical direction of the laser. With this setup the laser would be able to point at any point on the 2D plane of the thermochromic paper as long as it is set up vertically straight as shown in Figure 7 below [3].

The mount used in this design will also feature servo motors however unlike those in Figure 7, the servos in this design will be geared down on a 3:1 system such that 0.33 degree angular resolution is plausible, thus limiting the field of view on either axis to only 60 degrees. See the Tolerance Analysis section for more details.
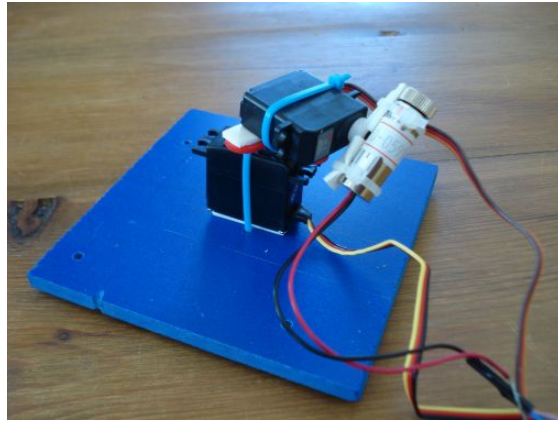

Figure 7: Dual Servo Motor Laser Guidance Setup

Table 3. Motor Requirements and Verifications

Requirements	Verifications
1. Motor must communicate with the microcontroller.	A. Program test code to check digital signal output to motor. B. Program test code that turns the motors each individually to verify signal output and correct output.
2. Motor must be able to run off 5 V supplied by the power module.	A. Multimeter test to verify there is a current flowing through each motor and at desired voltage tolerance.
3. Motors must be smooth enough to allow accurate alignment of laser beam to desired pixel.	A. Write testing code that checks to calibrate the speed at which it will move when heating the paper.
4. Mount and guidance must be able to direct the laser precisely within the 6 in by 6 in wire grid.	A. Write testing code that it can reach the positioning needed for the laser to aim at corner points of the grid.

Laser

This unit consists of a single high-powered laser capable of heating a 3 mm by 3 mm square on the thermochromic paper to a range of 30 ℃ to 35 ℃. As outlined in the wire gird section, only a small portion of pixel space on the thermochromic paper is exposed to the laser, hence the 3 mm by 3 mm heating requirement. The effective intensity of the laser can be modulated either via controlling the current to the laser diode or via pulse-width modulation with a static current load. Pulse-width modulation will be used to simplify the laser circuit. The heating of the paper would be based on how much power the material absorbs from the laser, this will largely depend on the wavelength of the beam and the material of the paper. To ensure the appropriate power is delivered to the material, as mentioned in Table 4, we will need to test how much energy is needed to just change the color of the material without reflecting harmful energy or burning through the material which we can do through various laser intensity-absorption equations [4]. We will need to run tests to find the right energy required for specific colors on the specific thermochromic material. Essentially the lower the energy required, the less likely it is to burn the paper. Further, the more precisely the wavelength range reflected by the paper is configured the less likely it will burn through, especially since the metal wire mesh will diffuse the heat quickly and safely. Using energy equations and Beer Lambert's Law below, we can have our system calculate and adjust the laser accordingly per pixel:

$$E \ = \ h\nu \ = \ \frac{hc}{\lambda} \tag{1}$$

$$I(z) = I_0 \ exp(-\alpha t) \tag{2}$$

Where E is energy, h is plank's constant, c is speed of light, λ is wavelength, and α *is* absorption coefficient dependent on wavelength, material and intensity.

Table 4. Laser Requirements and Verifications

Requirements	Verifications
1. The laser must provide enough power/energy to trigger thermochromic color change between 30 ℃ and 35 ℃.	A. Test in a safe and enclosed area against a heat absorbing material. B. Use temperature sensor on grid while laser is heating to verify temperature range.
2. Laser intensity must be controlled through pulse-width modulation.	A. Verify with datasheet for laser circuit B. Test varying modulations and values to verify that intensity changes accordingly.

Controller Module

The controller module takes standard video or image data via USB as well as the signal input from the gyroscope and converts it into control signals. These signals control laser intensity and angle laser mount system to create a final render on the thermochromic paper.

Microcontroller

The microcontroller ties each component of the controller module together. It will run code which factors in gyroscope and image data and outputs laser and motor controller signals to aim the laser appropriately. Requirements further elaborated in Table 5. Based on ambient temperature recorded by the temperature sensor the microcontroller will modulate the absolute intensity of the laser to precisely heat the thermochromic paper between its operating range (of 30 ℃ to 35 ℃). This design will utilize an ATMega328P controller since this design does not require any highly intensive computer and it has support for a variety of communication protocols including SPI, I2C and UART.

Table 5: Thermochromic Requirements and Verifications

Requirements	Verifications
1. Can receive data input from the gyroscope for two axes to calculate which pixel the laser is aimed at.	A. Test code to visualize the data inputs and cross check with the actual orientation of the sensor.
2. Has at least ten I/O ports to take input from the gyroscope and the temperature sensor and send output to the motors to control the laser.	A. Cross check with data sheet. B. Write test code to test data input and output for each module.

Gyroscope

This sensor enables the detection in the change of orientation in an object, or rather, any change in the location of the chip itself will be registered and used to detect a movement. The gyroscope measures rotational velocity or rate of change of the angular position over time, along the X, Y and Z axis. We plan to use the GY-521 module as an MPU-6050, which is an inertial measurement unit. It combines an accelerometer and gyroscope on a single chip, as well as a digital motion processor. It uses MEMS technology and the Coriolis Effect for measuring. The main function we need is the gyroscope which is able to measure the angular rotation of an object along those three axes. Rotation in three dimensions can be described by rotation along

these three axises: X-axis: left-right (pitch), Y-axis: forward-back (roll), Z-axis: up-down (yaw). It reads the raw data and sends them as variables to the microcontroller.

This will be used to calculate where the laser should be directed to heat up the appropriate pixel on the paper. We plan to verify the setup as mentioned in Table 6.

Table 6: Gyroscope Requirements and Verifications

Requirements	Verifications
1. Gyroscope should be able to send data bits from the two degrees axes that it captures to the microcontroller.	A. Test code to visualize the data inputs and cross check with the actual orientation of the sensor.

Temperature Sensor

This sensor is used to measure ambient temperature during operation for calibration purposes. Based on the ambient temperature the base laser intensity will be modulated to ensure that the thermochromic paper is heated to stay within its operating range. The software module to take this input will test as described in Table 7.

Table 7: Temperature Sensor Requirements and Verifications

Requirements	Verifications
1. Should be able to determine ambient temperature in a range between 20 ℃ and 40 ℃ within ∓1 ℃ .	A. Test code to read temperature and cross check with a physical thermometer.

USB Adapter

The USB Adapter takes in standard video input as PNG or JPEG and converts it into a format usable by the microprocessor. Originally the use of VGA or HDMI was considered however considering the resolution is only 25 pixels by 25 pixels the added complexity and bandwidth was deemed unnecessary. A standard FTDI chip can effectively convert USB into UART protocols and we can verify a prototype as mentioned in Table 8.

Table 8: USB Adapter Requirements and Verifications

Requirements	Verifications
1. Should be able to read in PNG and JPEG data from usb input.	A. Test code to verify format of data input and readability. B. Connect to screen to visualize the data input.

Power Module

This unit routes appropriate power to each submodule. Since the device is designed for non-portable, static use, a wall supply is used.

Wall Outlet

A standard wall outlet operating at 120 V 60 Hz AC will be used as the main input to our system. Paired with a DC adapter, voltage will be stepped down to that usable by the voltage regulators of our choice. The laser and motor are the largest power users of the system however power will likely be less than 10 W once we verify using steps listed in Table 9.

Table 9: Wall Outlet Requirements and Verifications

Requirements	Verifications
1. Steady 10 W power provided to the device throughout the usage.	A. Using a multimeter at the input pin to measure the input and output voltage.
2. To prevent explosions, surge protection should be provided.	A. To avoid problems with spikes, we need to check the voltage threshold and ensure that the accurate voltage tolerance goes to ground.

Voltage Regulator(s)

This integrated circuitry steps down high voltage from the supply to the required 5 V, 7 V, and 12 V. These power lines are then routed to their respective submodules. Table 10 outlines requirements of the regulator circuit and their verification procedures.

Table 10. Thermochromic Requirements and Verifications

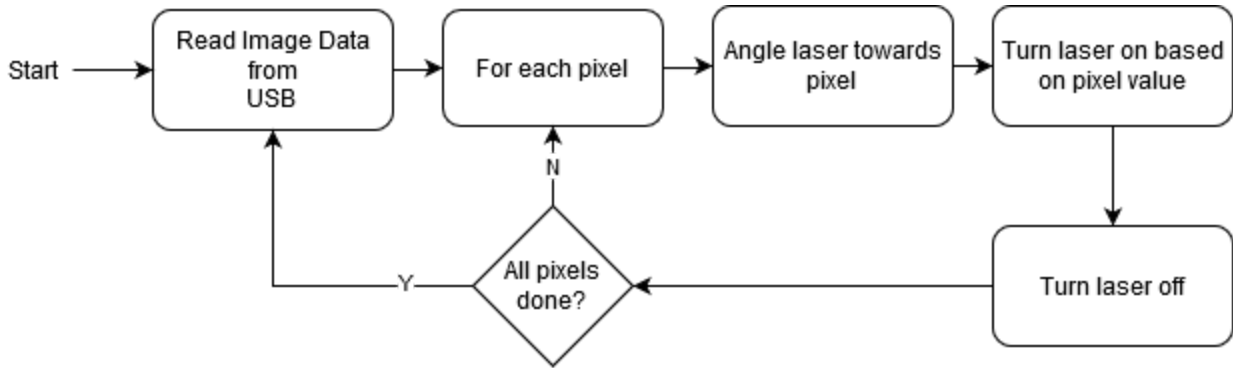| Requirements	Verifications
1. Must be able to attain steady 5 V, 7 V and 12 V (+/- 5%) supply by converting DC output from the wall.	A. Using a multimeter at the input pin to measure the input and output voltage.

2.4 Software

Figure 8: High-Level Software Flow

Figure 8 demonstrates the high level flow of software on the microcontroller. As illustrated, the microcontroller will run a simple loop which reads image data from the USB adapter then renders it on the thermochromic paper pixel by pixel. While not shown in the flowchart, pixels will be rendered row by row for efficiency and accurate guidance. By factoring in readings from the gyroscope pixel location can be determined precisely.

At each pixel location, the microcontroller will turn on the laser at the appropriate effective intensity for a fixed period of time before moving the laser to the next pixel. This intensity is modulated by pulse-width modulation of the laser at a fixed instantaneous intensity and is based on the pixel color and ambient temperature as read from the temperature sensor.

2.5 Tolerance Analysis

A key difficulty to tackle is the accurate control of the laser dot on the thermochromic paper. To maintain this accurate control, the mount is designed such that the emitting end of the laser diode remains at the same point regardless of laser orientation. With this assumption in mind, the system can be mapped to two, single axis systems as illustrated in Figure 9.
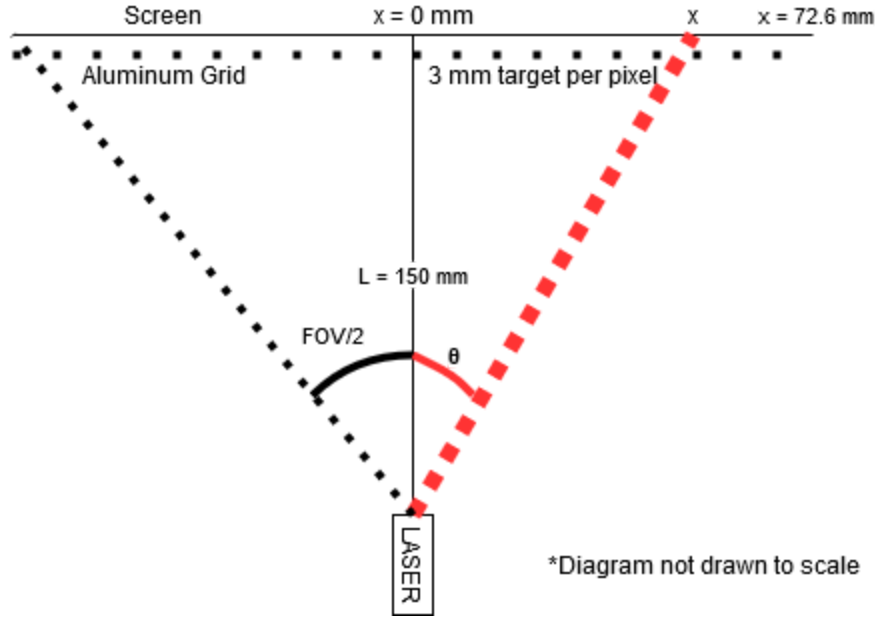
Figure 9: Single-Axis Simplification of Laser Setup

As depicted in Figure 9, while the target for each pixel is only 3 mm, the spacing from the center of each pixel to the next is actually 6 mm. By extension, the minimum angular resolution of the laser mount must result in at most 6 mm change in 'x' (the position where the laser makes contact with the thermochromic paper backing). Using basic trigonometry, the position 'x' can be modeled by Equation (3). When 'L' is small a higher angular precision is required to effectively hit the farthest corners of the sheet, however when 'L' is set to 150 mm, Equation 1 can be approximated linearly by Equation (4) simplifying the mapping calculation.

$$x = L * tan(\theta) \tag{3}$$

$$x = 76.2 * \theta / 26.93 \tag{4}$$

By extension, the 6 mm jump from the center of a pixel to the center of the next pixel correlates to a 2.120 degree change in the angle θ. By extension, the field of view required (25 times the angle change for a given pixel) is only approximately 54 degrees. A servo motor geared down has an angular precision of 1 degree in a range of 180 degrees. The gear system proposed features a 3:1 reduction thus allowing each axis a range of 60 degrees with a precision of 0.33 degrees. This allows a large window to precisely center the laser on each pixel.

Another point of analysis is the time spent to heat up each pixel. The final color of each pixel on the thermochromic paper is directly related to the temperature the paper is heated to. As this set temperature target rises, the time it takes to heat up increases as well. The pixel color and location will be set in place by the software and the motor will rotate the laser to aim at the

desired position. In order to minimize the potential of other (unintended) pixels getting heated up by the laser, we make use of a relatively thick aluminum mesh to absorb excess heat. The aluminum grid also enforces frame divisions of each pixel. As a result of this wide aluminum grating it is not critical to hit each pixel directly centered on the exposed paper backing since heat will be contained by the aluminum grid to a limited pixel range.

3. Comparative Analysis

3.1 Overview

While the design outlined in this paper follows Spring 2019, Team 36's inspiration to use thermochromic paper and a heating mechanism to display images, it differs greatly in approach. Team 36's original plan yielded a 6 in by 6 in square thermochromic display as well, however, as Equation 5 demonstrates, it only featured 45 pixels arranged in a 5 pixel by 9 pixel array. Each of these pixels were heated by a nichrome resistive heating element which was pressed into the back of the thermochromic paper. Each nichrome wire sat on a MOSFET-based supply circuit which was controlled by the microprocessor through intermediate shift registers.

$$Total\ Pixels_{original} = 3\ cells\ *\ (3\ columns\ *\ 5\ pixels\ /\ column)\ /cell\ =\ 45\ pixels \qquad (5)$$

$$Total\ Pixels_{new} = 25\ columns\ *\ 255\ rows\ *\ 1\ pixel/(row\ *\ column)\ =\ 625\ pixels \quad (6)$$

$$Pixel\ Ratio = 625\ pixels\ /\ 45\ pixels\ =\ 13.889 \qquad (7)$$

The laser-based design outlined here improves on the resolution of the screen and fundamentally changes circuit requirements for the heating element, i.e. the laser and mount. The proposed design is able to split the 6 in by 6 in display into a total of a stunning 625 pixels in Equation 6: 13.889 times that of the original as calculated in Equation 7. Unfortunately, more effort must be devoted towards the physical design of the screen since moving parts must be incorporated into the screen.

Unlike the previous project, which has to heat nichrome the varying temperatures to obtain the desired color effect, this project uses a fixed intensity laser diode that modulates its effective intensity via pulse-width-modulation of current through the diode. This modulation allows for controllable amounts of energy, and thus heat, to be deposited onto the liquid crystal sheet to achieve the desired temperature and color change.

Further, the previous project used physically separated rectangles supported by a large aluminum heat sink to form pixels, however this design proposes the use of one physical sheet of thermochromic paper with pixel boundaries enforced by a thin aluminum grating. The use of a grating in tandem with a laser permits a higher pixel density.

3.2 Analysis

As outlined above, this design capitalizes on the precise control capable with a laser in order to improve the resolution of the display significantly. The original design split the 6 in by 6 in display space into three, 3 pixel by 5 pixel display segments thereby setting pixel size at roughly 10 mm by 17 mm pixels.

Since this design aims to split the display space evenly into a 25 pixel by 25 pixel array, pixel size is maximized at approximately 6 mm by 6 mm (6.096 mm by 6.096 mm). As detailed in the aluminum grid portion of Section 2, this leaves between a 3 mm by 3 mm to 4 mm by 4 mm square of the thermochromic paper exposed to the laser per pixel. Diode based lasers with wavelengths between 405 nm and 1064 nm typically have a circular beam with a diameter of between 2.5 mm and 5 mm [5]. As such, the laser can effectively be aimed at the exposed backing of the liquid crystal sheets. The laser can then effectively heat the individual pixels with much greater resolution than the previous project. In fact, as illustrated by Figure 10, the laser-based design presented here includes over 13 times more pixels.
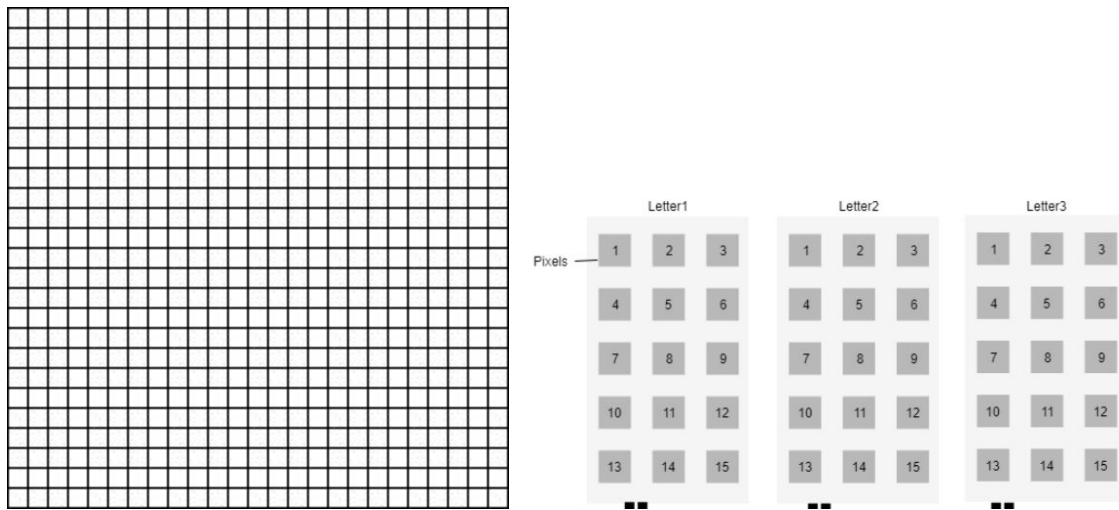

Figure 10: A Comparison in Resolution, Laser-Based (left), Original (right)

Empirical testing will yield further information regarding the speed of heat dissipation through the thinner aluminum grating when compared to the larger heat sinks used in the previous project. Depending on how effective heat transfer to the mesh is relative to heat leakage, a thin, physical, thermal barrier between the pixels may be required. This could easily be achieved by cutting a thin line on the front face of the singular, 6 in by 6 in sheet along the aluminum mesh boundary (effectively using air to form the thermal barrier between pixels).

4. Cost and Schedule

4.1 Cost Analysis

Fixed costs for designing this project include a $40 per hour salary paid to each of three partners. Assuming a 15 hr per week schedule and that only 60% of the 15 week course is spent working, the labor cost can be estimated by Equation (3) to be $42,300.

$$Labour\ Cost\ = 2.5 \times \frac{\$40}{hour} \times \frac{15\ hours}{week} \times 16\ weeks \times 60\% \times 3\ people = \$42,300 \qquad (8)$$

Table 11: A Summary of Costs

Part #	Source	Description	Unit Cost	Quantity
LC-3035A	NGSS Correlations	12 in by 12 in Liquid Crystal Paper Sheets	$25.95	1
ATMega328P	ECE Supply Shop	Microcontroller	$6	2
PCBs	PCBWay	Laser and Motor Control PCB	$25	2
Heating Laser	eBay	250mW power focusable laser module	$10	1
Motor	eBay	Brushless Low speed DC motor	$15	2
Aluminum Grating	ECE Machine Shop	Machined Aluminum Plate	$5	1
Frame	ECE Machine Shop	Simple Housing for Screen	$20	1

Laser Mount	ECE Machine Shop	Assorted Items for Mount (bearings, gears)	$10	1
Assorted electrical components	ECE Supply Shop and Digikey	Resistor, Capacitor, IC, Crystal, Socket	$25	~
Total	-	-	$141.95	-

Table 11 outlines part costs which total to $141.95. By extension, total costs will amount to $43,441.95.

4.2 Schedule

Table 12 outlines a tentative build schedule. Generally early weeks are dedicated to design and prototyping with an emphasis on finalizing parts and working out kinks in circuitry early on. Later weeks are focused on assembly, testing and verification.

Table 12: Estimated Design and Build Schedule

Week	Pavan	Taofik	Charles
1	-Start design for laser heating -Look into Microprocessor for control -Determine Serial Communication Method	-Design laser mount and motor position -Reach out to machine shop -Work on power module design	-Look into software conversion of pixel intensity to laser intensity -Work on power module design
2	-Start testing laser heating prototype on liquid crystal sheets	-Follow up machine shop -Complete power module design	-Look into accurate control of motor and laser dot position
3	-Complete design of laser	-Submit final design and specs to machine shop	-Test basic control algorithms with

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3	heating circuit -Start PCB design	-Order parts	3D-printed parts and mount mock-up
4	-Place PCB Order	-Test laser mount system with breadboarded circuit	-Test control algorithms on breadboarded circuit
5	-Update laser heating circuit as needed	-Revise Machine shop design -Update power module design as needed	-Test advanced control code on mock-ups
6	-Place finalized PCB order in case of error	-Assemble and test power module	-Continue advanced control code testing
7	-Assemble full setup	-Assemble full setup	-Test advanced control algorithms on full setup
8	-Test Demo of individual modules	-Test Demo of individual modules	-Test Demo of individual modules
9	-Complete final documentation	-Complete final documentation	-Complete final documentation
10	-Complete final demo	-Complete final demo	-Complete final demo
11	Prepare Final Presentation and Begin Final Report		

5. Ethics and Safety

We regard the safety of the public in high esteem, therefore we have taken measures to prevent any possible harm to viewers and users. In the aspect of electronic safety we are drawing power from a wall outlet which is at 120 V. We plan on maintaining safety by using a voltage regulator which would power our projects at safe rates of 5 V, 7 V and 12 V to the respective components. We would have also covered all wires properly and tucked away from exposure in order to prevent direct contact with any person.

There are some concerns involved with the laser, especially if it is contact with the skin due to radiation. This could bring about thermal injuries and/or more casualties [6]. Therefore, we have decided to use a protective casing over the laser and the thermal paper so they do not come in contact with human skin. More precautions such as gloves, goggles and a distance measure are being taken into consideration as a form of an extra layer of protection.

We recognise that maintenance is important so we have taken precautions to keep it at optimum ability. With the layer of mechanism that is involved with both the motors and the lasers, we know that a potential safety hazard could occur if rusted or unkept equipment is in exposure or used by others [7]. We decided to oil and disinfect equipment at regular intervals so that it'll be in top shape for the lasers and motors to be used. This falls in line with Article 9 of the IEEE Code of Ethics to avoid injuries to others and properties through our actions [8].

The use of a laser, where it sounds exciting to most, is actually very technical to use. Properly trained personnel must be the ones that use laser and proper training must be given to those planning to work on it. We made sure to all register and abide by the university's DRS Laser Safety Module and its guidelines in order to be qualified to operate such lasers [9]. On the other side of the spectrum we have decided that under no circumstances will those younger than the age of 12 and those unqualified to work with equipment will be allowed to work with the project. Consequently, this is a form of protection so those that may be unaware of the dangers do not misuse the project thus endangering themselves and those around them.

Overall from an ethical approach, we made sure to uphold the standards of the IEEE Code of Ethics [8]. We have the personal and physical safety of our viewers as our top priority, we do not tamper nor abuse the information given to us by users. We have the purpose of this project to be of the betterment of society and an avenue for the creativity of others' expressions. Our precautions align particularly with the Article 5 of the IEEE Code of Ethics, to improve the understanding of the people in society through our project. We aim to use this project to encourage others to think outside the box and provide alternatives to our modern day processes. We do not encourage the use of this to harm or threaten others but to invite variety in our lives.

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