October 27th, 2015

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6

Re: ENSC 440 Design Specification for the Dot Light Canvas

Dear Dr. Rawicz

The attached document is the Design Specification for Art Tech's project, the Dot Light Canvas. The Dot Light Canvas is a new and innovative art canvas that uses LED light in the place of paint. It will be used by new and seasoned artists alike to create unique artistic expressions that are bright, creative and engaging.

This design specification describes the design of the Dot Light Canvas Prototype model, which includes both unit and system design. It will also highlight the test plan for the product, which includes both system and unit testing.

The Art Tech team is made up of four Simon Fraser University engineering students; Zachary Cochrane, Dana Sy, Aman Shoker and Bhavit Sharma. If you have any questions or comments about this document or our project, please contact me at zwc@sfu.ca or through phone at (778) 378-6019.

Sincerely,

Zachary Cochrane
Co-Founder and Primary Contact
Art Tech

Enclosure: *Design Specification: The Dot Light Canvas*

Design Specification

The Dot Light Canvas

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Submitted To: Dr. Andrew Rawicz
Professor Steve Whitmore
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Date Issued: November 9th, 2015

Revision No: 1.0

Executive Summary:

This document provides a detailed description for the design and development of the Dot Light Canvas prototype model. Therefore, it will mainly address the functional specifications marked I or II, as outlined in the previous Art Tech document, *Functional Specification: The Dot Light Canvas* [1].

The Dot Light Canvas consists of an LED Array superimposed by a cloth canvas and an infrared touchscreen, all of which are housed in a canvas chassis. Users interact with the canvas through the use of a pressure sensitive Smart Stylus. The canvas combines location information sent to it from the touchscreen with pressure information from the smart stylus to illuminate the LEDs. The user will also have the ability to select what color they are painting with, and will also be able to switch the Smart Stylus from paint mode to erase mode.

Throughout this document, the Dot Light Canvas system and sub system design will be discussed. These sub systems include the Smart Stylus, the LED Array and the Canvas chassis, which includes the embedded IR touchscreen. As each sub system is discussed, the design decisions made will be justified and compared to other possible designs. We will also outline the design of the software implemented for both the Smart Stylus and the LED Array.

After the design of the Dot Light Canvas system has been discussed, the test plan will be outlined. Testing will include both unit and system testing and will follow a series of test cases, each of which must be passed in order for the canvas to be considered functional. Upon failure of a test, the offending subsystem will be revisited and revised until all tests are passed successfully. The system will also be tested against the functional specifications outlined in the previous Art Tech document, *Functional Specification: The Dot Light Canvas* [1].

The Dot Light Canvas System Prototype is currently under development and is scheduled for a completion date of December 18th 2015.

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1.0 Introduction

The Dot Light Canvas is an electronic painting canvas that uses Light Emitting Diodes (LEDs) for illumination. The canvas will consist of an infrared touchscreen (IR) mounted over a cloth painting canvas that will overlay an LED array. Users will be able to 'paint with light' by applying a smart stylus to the IR touchscreen, activating the LEDs behind it to illuminate the canvas in a variety of user specified colors. This document describes the technical design specifications of the Dot Light Canvas prototype model, including hardware and software design. The system test plan, design justifications as well as future design considerations will also be discussed.

1.1 Scope

This document specifies the technical design of the Dot Light Canvas system, and how the design will meet the functional specifications as outlined in the document *Functional Specification: The Dot Light Canvas* [1]. Note, this document describes the design of the prototype version only. All schematics, diagrams and design decisions made pertain to functional requirements marked with I or II in the functional specification document.

1.2 Intended Audience

This document is intended for use by the Dot Light Canvas design team of Art Tech. All members of the team shall refer to this document as both a development and testing guideline. During implementation of the Dot Light Canvas and any of its subsystems, this document should be consulted and used to ensure all requirements are met by the final prototype system. During testing, the test cases contained in this document should be followed, and the system behavior should follow the expected outcome of each test case.

2.0 System Specifications

The Dot Light Canvas is a touch based canvas that uses LED light to illuminate a cloth canvas screen from behind. The LEDs turn on at the position that corresponds to the touch of a smart stylus. When the smart stylus is brought in contact with the canvas, the IR frame will record the co-ordinates of the touch and the microcontroller on the smart stylus will collect the information on how much pressure is applied on the screen. This information is sent the main controller embedded in the canvas. The canvas controller will use the pressure and position data to light up the LED in that particular location. Figure 1 shows the overview of the Dot Light Canvas. Figure 2 shows a SolidWorks view of the Dot Light Canvas system. The individual component specifications and their functionality will be described later in their own sections.

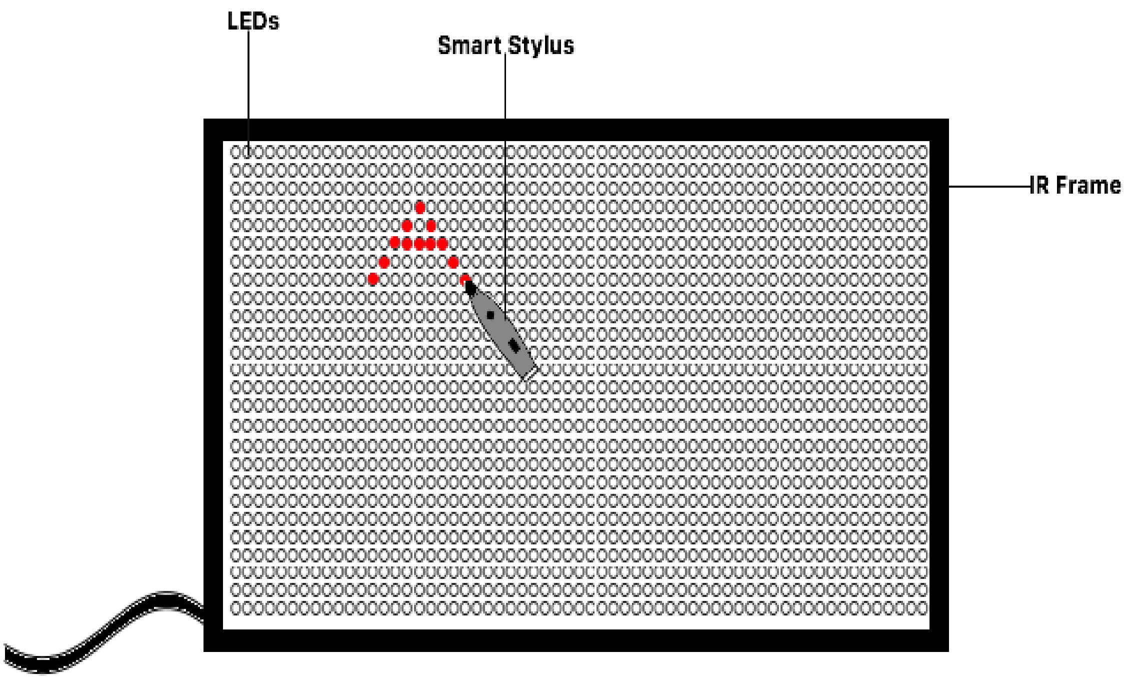


Figure 1: Graphic model of Dot Light Canvas

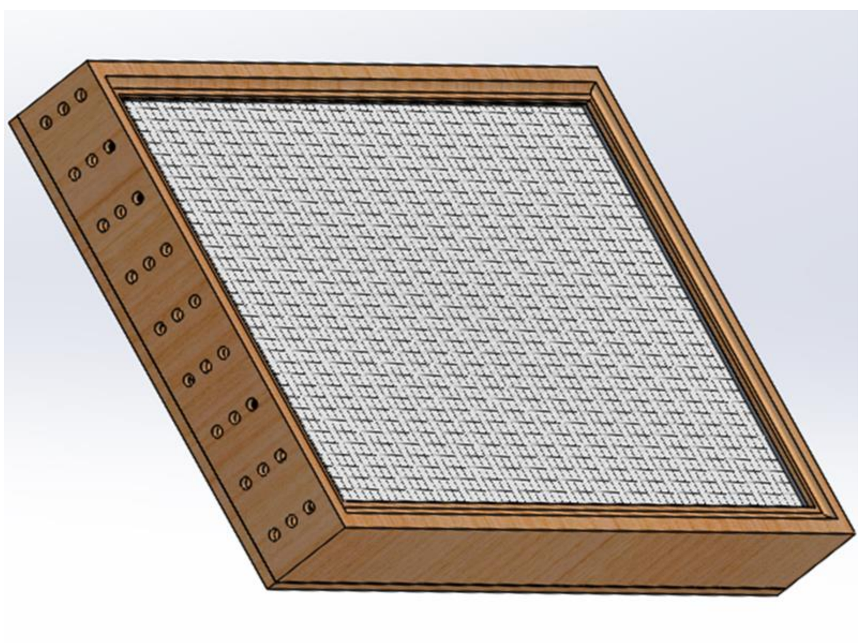


Figure 2: SolidWorks view of Dot Light Canvas

3.0 High Level System Design

The Dot Light Canvas System consists of two main components; the canvas itself and the Smart Stylus. The Canvas can be further broken down into two distinct but equally important components; the Canvas Chassis, and the LED Array.

This section gives a high level overview of the Dot Light Canvas system, and will act as a blueprint that will be used to design prototype and the final product. The three major components will each be discussed in depth in their own sections later on.

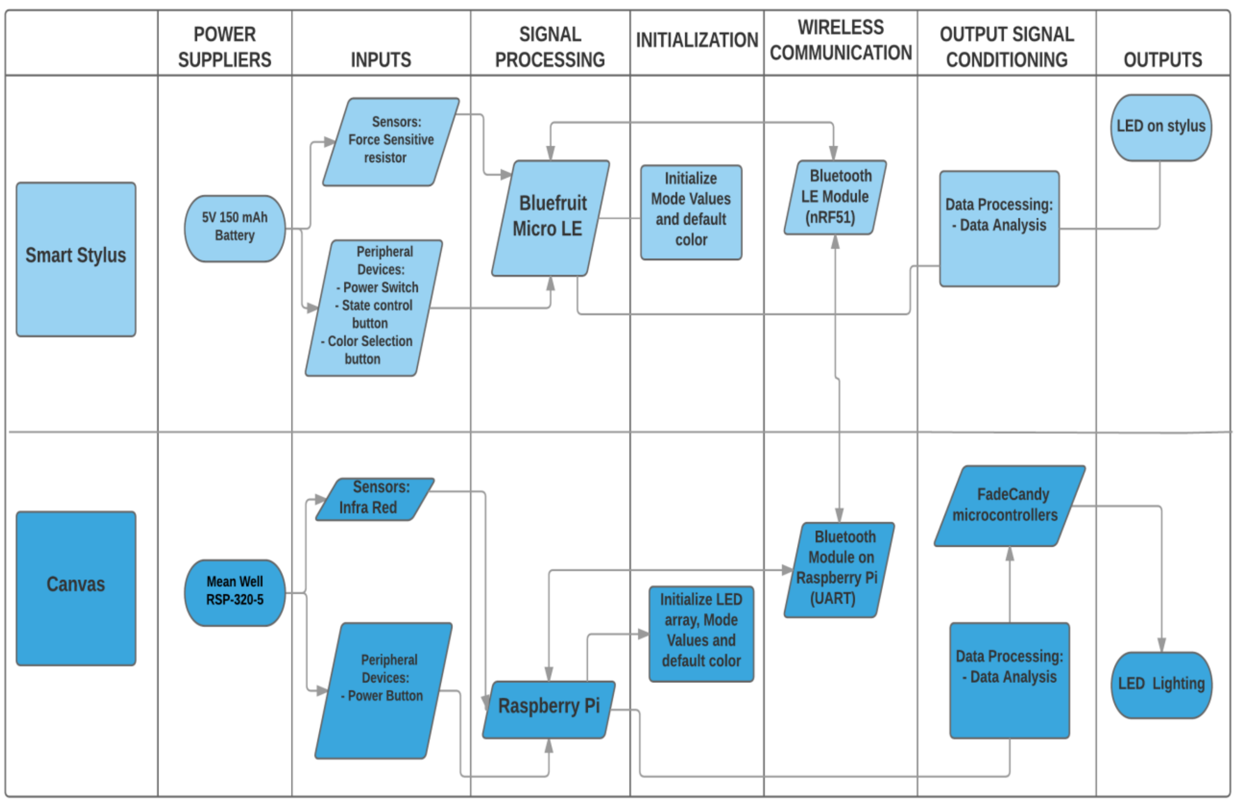


Figure 3: High Level Block Diagram of Dot Light Canvas

The Dot Light Canvas can be modeled at a high-level as shown in figure 3. This is a simplified and organized overview of the overall systems design of the two main components, the Smart Stylus and the Canvas.

Firstly, we will discuss the Smart Stylus. The Smart Stylus is battery powered. The battery will power a microcontroller, which will be receiving inputs from various buttons and sensors. The microcontroller will then communicate these inputs to a second microcontroller in the canvas. A more detailed look at the Smart Stylus design is given in section 5.

The canvas consists of an LED Array a chassis embedded with an infrared (IR) touchscreen. The canvas draws power from a power supply connected to a standard wall outlet. The touchscreen and the LED Array are synchronized by a microcontroller, which also handles the input coming from the Smart Stylus. The microcontroller takes these inputs and uses them to calculate the brightness, color and location of the LED light projected on the screen. The canvas chassis and IR touchscreen are discussed in section 4, while the LED array and canvas software are discussed in section 6.

4.0 Canvas Chassis

The canvas is the body of the Dot Light project. It holds all components except for the Smart Stylus.

4.1 Physical Design

The canvas consists of an IR frame, an acrylic touchscreen, a cloth canvas and the LED Array as well as the arrays electronic circuit and power supply, which will be discussed in section 6. These components are housed in a cedar chassis measuring a length of 785mm, height of 465mm, and a width of 90mm. An exploded view of the SolidWorks design of the canvas chassis and components it houses can be seen in Figure 4.

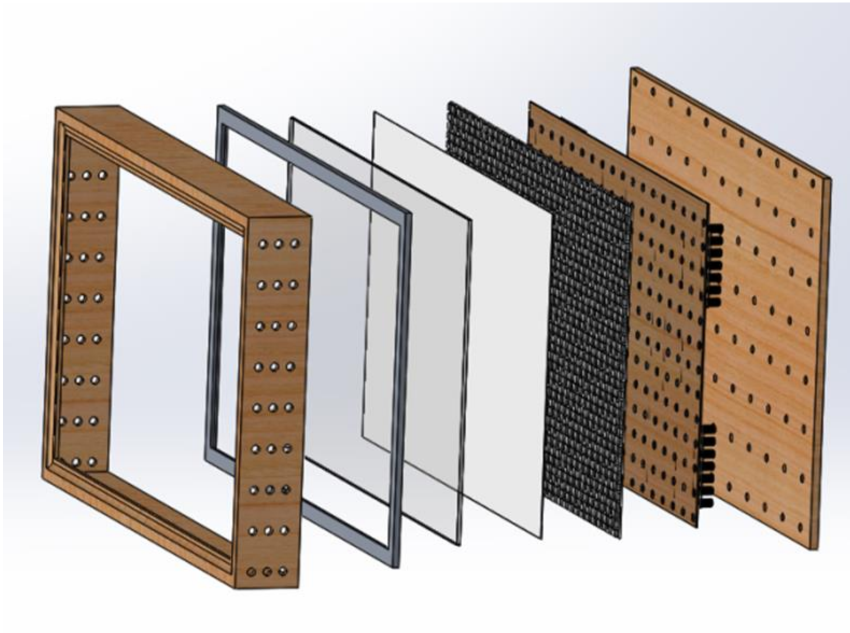


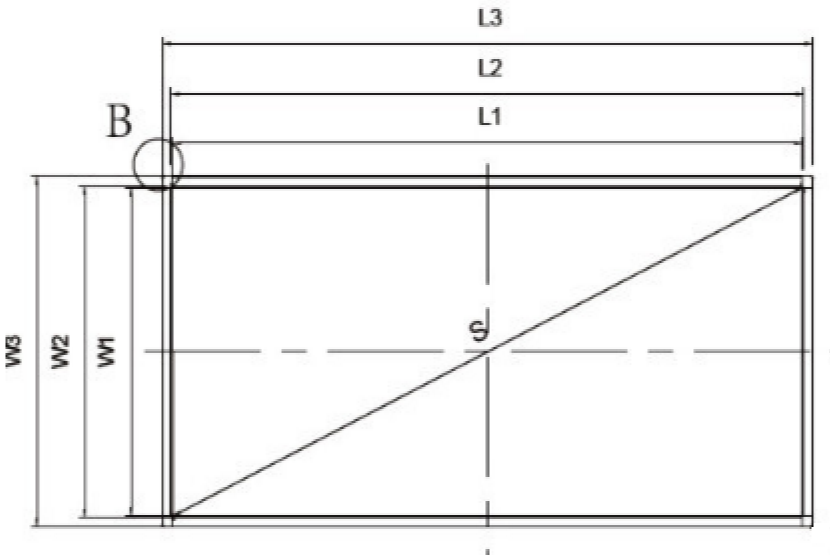
Figure 4: Exploded View of Dot Light Canvas and Chassis

4.2 Infrared Touchscreen

One of the most fundamental components of the Canvas is the infrared touchscreen, which consists of an IR frame, a sheet of acrylic glass and a cloth canvas. The touch screen is essential in linking the communication between the Smart Stylus and the LED array, causing the LEDs to illuminate wherever the Smart Stylus touches. Art Tech has chosen the NECO-X IR Touchscreen [2] for use with the Dot Light Canvas because of its high refresh rate, desirable 32” size and USB connectivity, used to communicate with the canvas microcontroller.

An infrared touchscreen was utilized instead of a capacitive touch screen due to size constraints and material properties. While both options exhibited accurate touch recognition and response times. The infrared touchscreen is easily scalable whereas the capacitive touchscreen is difficult to scale up or down in size due to product availability. The infrared touchscreen also proved to be a more cost effective solution. The infrared touchscreen is surprisingly very light allowing for easy movability and is of an aluminum material.

The dimensions of the infrared frame are shown in figure 5.



S(Inch/mm)	31.72"/805.6
W1	395.3
W2	397.5
W3	433.3
L1	702.1
L2	704.3
L3	740.1

Figure 5: Physical dimension of the IR touchscreen [2]

A sheet of acrylic glass will be cut to roughly the same dimensions and securely fit to the back of the infrared frame. Immediately behind the touchscreen is the cloth canvas.

The infrared touchscreen panels have pins which can be inserted into a locking square mechanism which will lock the adjoining panels securely into place and connecting the as shown in figure 6.

Figure 6: How the IR frame is constructed [2]

The acrylic glass with dimensions of 704mm wide and 397mm tall is adhered to the back of the touchscreen, and is preferred over other materials because of its high light transmissivity rate of 92%, excellent impact strength, low density, and is water resistive.

4.3 Chassis

One of the most important design considerations for the canvas component is to create a canvas that is light enough for use and transportation, yet durable enough to withstand operational and functional abuse. For this reason, the Canvas chassis prototype shall be constructed using cedar wood, also chosen for its availability and excellent working characteristics. Wood can be easily machined and assembled compared to other materials such as metals and is readily available. The wood utilized in creating the chassis is spare cedar wood from a home renovation.

Cedar has great properties that can be advantageous to the overall design of the product. Firstly, Cedar wood is known to absorb and dampen sound vibrations which will ensure the canvas generates less than 20 dB of noise, thus meeting functional requirement [R23-II] from the functional specification [1]. Cedar is also a fairly light low density wood which is perfect for transportation purposes and is dimensionally sound and structurally secure, not changing in shape or warping under different weather conditions [3]. Another admirable aspect of wood is its material property of not conducting electricity, which is of great important since the chassis will be housing a significant amount of electrical components.

4.3.1 Chassis Construction

The chassis will be machined using a Miter Saw which is capable of cutting angles ranging from 30 – 90 degrees and a Radial Arm Saw if necessary. The wood surrounding the infrared touch screen will be cut into 4 pieces, each at 45 degree angles, being glued and clamped down. Further structural stability can be provided by using an air pressure nail gun. Enclosing the sides and the back of the Canvas will follow similar steps such as machining the wood to the appropriate dimensions then assembling the parts using glue and clamps, and if necessary using a nail gun to further improve the structure.

The infrared touchscreen along with the acrylic glass and cloth combo will fit securely into the wooden chassis interior grooves, and extra space for the wiring will be left on the back of the chassis.

The LED array is placed 2 cm behind the clot canvas, allowing space for heat dissipation and to allow room for the LED colors to mix together slightly. Another 4 cm of room is left behind the LED array, which takes into consideration the increase in bulk caused by the wiring and the size of the electrical components such as the power supply, PCBs, buses and micro controllers.

4.3.2 Heat Dissipation

While the Dot Light Canvas is operating, the emission of heat from the electrical components and the LED arrays must be taken into consideration. The chassis will be machined and engineered with air holes along the side to allow for the dispersal of heat.

Enclosing the back end of the chassis will be a MDF board with pathway holes to allow for heat dissipation from the power supply fan and other electronic components

4.4 Further Design Considerations

At this time, a white cloth has to be situated behind the acrylic glass to reduce the strain and exposure of the bright LEDs on the eye. The cloth will be spread over the acrylic glass and glued along the sides of the glass. The exact used for this step however is subject to change, as different mediums are tested for their light dissipation properties and aesthetic appeal.

Another design aspect being considered is the use of a reflective grid that projects the light emitted from the LED arrays upwards, creating a pixel-art appearance. This would be installed over the LED array and behind the cloth canvas, and aid in reflecting the light from a single LED upwards. Polycarbonate panels used in green houses are the front runners for the material and design as of now. The polycarbonate panels can be glued onto the MDF backboard on which the LEDs are currently placed on. Again, this design choice is subject to change depending on how light transmits through the cloth medium and how the reflective grid changes the final look of the product.

Finally, future iterations of the chassis will be constructed from aluminum, and the IR frame will be integrated directly into the chassis. The use of aluminum will allow the chassis to be machined automatically and with ease, and will be lighter than cedar while being just as durable. The chassis will also be redesigned to fit the slimmer design and circuitry of the final version. It will be able to be attached to a custom stand, which is not included in the prototype, as well as have the ability to be mounted on the wall in either a portrait or landscape fashion.

5.0 Smart Stylus

The Smart Stylus is the main tool with which a user interacts with the Dot Light Canvas. The ability to switch between Paint Mode, Color Selection Mode and Erase Mode are made available to user through the Smart Stylus. The Smart Stylus also is the only tool that the user can use to paint on the canvas, which is done by applying its tip to the surface of the canvas infrared touchscreen.

5.1 Physical Design

The Smart Stylus needs to be compact and comfortable for anyone to use. Therefore, Art Tech decided that the physical dimensions for the pen should be no more than 190 mm in height and 30 mm in diameter, which is consistent with the functional requirement R85-II [1]. All the parts of the Stylus should be safely and neatly hidden inside the body of Stylus. Figure 7 below shows the SolidWorks front and side views of the Smart Stylus pen.

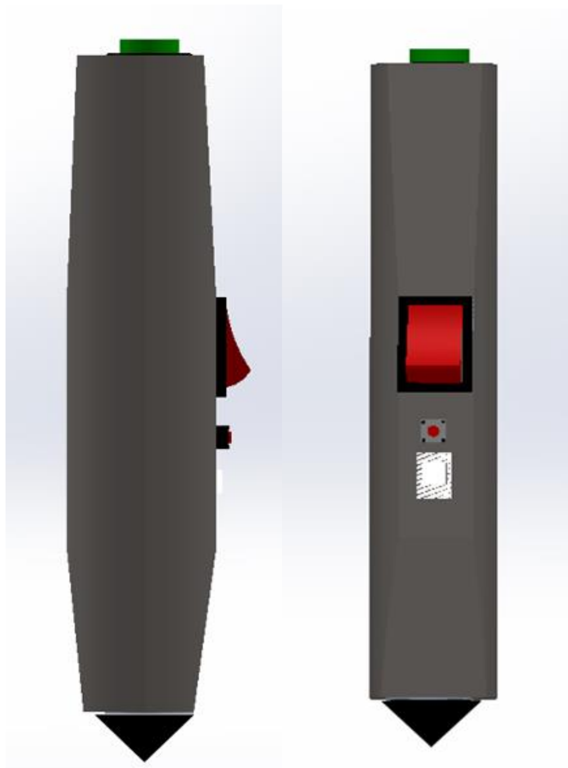


Figure 7: SolidWorks views of the Smart Stylus pen

5.2 Component Specifications

The components used in the construction of the Smart Stylus consist of the following: one Adafruit Bluefruit Micro LE microprocessor [4], a Force sensitive resistor (FSR), an LED pushbutton switch, a tactile button switch, a rechargeable 3.7V 150mAh Lithium Ion Polymer battery, an ON/OFF switch button and one WS2812b LED, which indicates the current color selected.

The Smart Stylus receives input signals from its various sensors and buttons and then sends relevant information via Bluetooth to the main Raspberry Pi 2 model B microcontroller [5] embedded in the in the Canvas. The FSR, hidden underneath the ductile tip of the Smart Stylus, is responsible for detecting how much pressure the user is applying to the canvas surface. The tactile button switch embedded in the shaft of the smart stylus is responsible for signaling the microcontroller, causing a color change operation to occur. This will cause the canvas to display a color wheel, allowing the user to select a color with the Smart Stylus. The push button, when depressed, indicates the smart stylus is in paint mode. When not depressed, the smart stylus is in erase mode. The battery, connected directly to the Bluefruit Microcontroller, provide the color indicator LED, the push button and the microcontroller with power.

5.2.1 Bluefruit Micro LE

To implement all the functions of Smart Stylus, Art Tech decided to use the Bluefruit Micro LE microprocessor provided by Adafruit [4]. This particular microprocessor was selected due to its micro size, light weight (5.6g), Bluetooth functionality and low power consumption. This fulfills the R81-II, R8-II, R9-II, R40-II and R88-II functional requirements [1]. Figure 8 describes the pin assignment of the Bluefruit Micro LE development board. The main purpose of the board is to collect all the data from Stylus components and relay it to the Raspberry Pi on the canvas via Bluetooth.

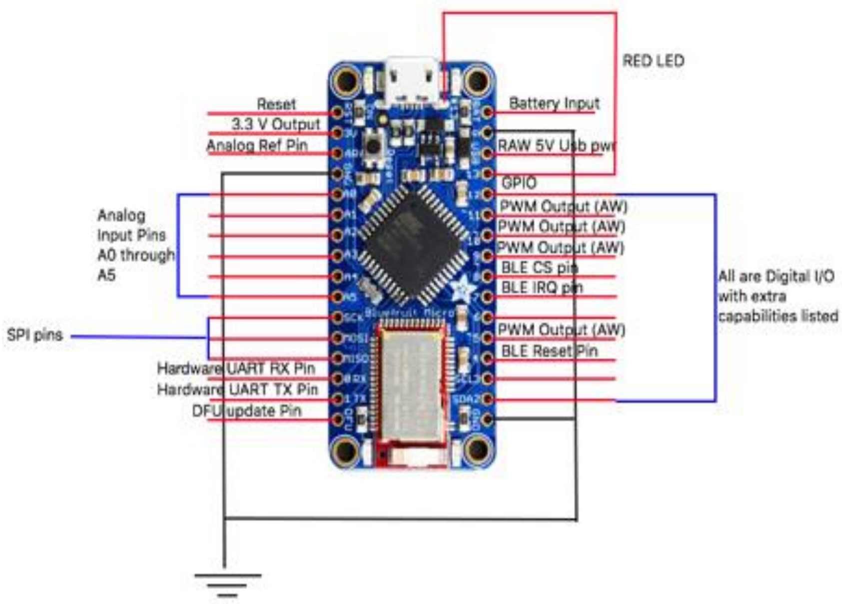


Figure 8: Pin Outs for Bluefruit Micro LE [4]

5.2.2 Force Sensitive Resistor

To meet the R80-II functional requirement of the Smart Stylus, a Force Sensitive Resistor has been chosen by Art Tech for use in capturing pressure data. As it is a resistor, it doesn’t need a direct connection to the power supply, so the 5V power from Bluefruit Micro’s USB pin is sufficient. Also, being a resistor, it does not have a polarity.

The FSR used was chosen for its small diameter and its force range, which roughly corresponds to the force applied by someone while writing [7]. Its construction can be seen in Figure 9 below, and its electric parameters are shown in table 1.

Table 1: Electric Parameters of the FSR [6]

Resistance Range	100kΩ (light pressure) to 200Ω (max. pressure)
Force Range	0 to 20 lb. over 0.125 square in surface area
Power Supply	N/A
Active Diameter	0.5 inches

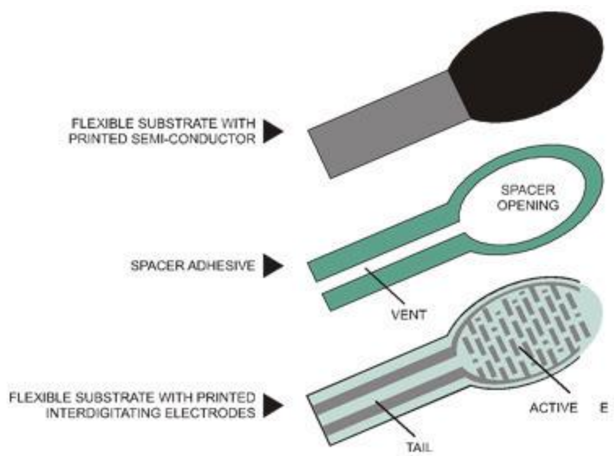


Figure 9: Round Force Sensitive Resistor construction [6]

5.2.3 Tactile Switch

The Tactile switch used was selected by Art Tech due to its small size (6mm X 6mm), required by the Smart Stylus physical design. The purpose of the tactile switch is to signal the Bluefruit microcontroller with an event which in return signals the main controller on the canvas, telling it to switch to color selection mode.

Table 2: Electric Parameters of the Tactile Switch [8]

Max. Voltage	12V
Max. Current	50 mA
Dimensions	6mm X 6mm

5.3 Power Delivery

The smart stylus will be powered using a rechargeable 3.7V 150 mAh Lithium Ion Polymer battery. The battery should be small and light, 19.75 mm X 26.02 mm X 3.8mm in dimensions and 4.6 g in weight. Therefore, the PKCELL LP402025 [9] battery was selected by Art Tech as a suitable choice of power supply for Smart Stylus.

5.4 Electronic Circuit Design

The circuit for the Smart Stylus must be compact and must be able to fit in the stylus chassis. Therefore, it has been kept as simple as possible while enabling all functionality needed by the Smart Stylus pen.

The pushbutton switch and tactile switch are connected to pins 12 and 6 of the microcontroller, respectively. Power is supplied through the battery input pin, and the LED color indicator is connected to GPIO pin 11.

The FSR makes use of the 3.3V output pin and returns its data to the analogue input pin A0. A diagram of the circuit used in the smart stylus can be found in figure 10, and a SolidWorks design can be seen in figure 11.

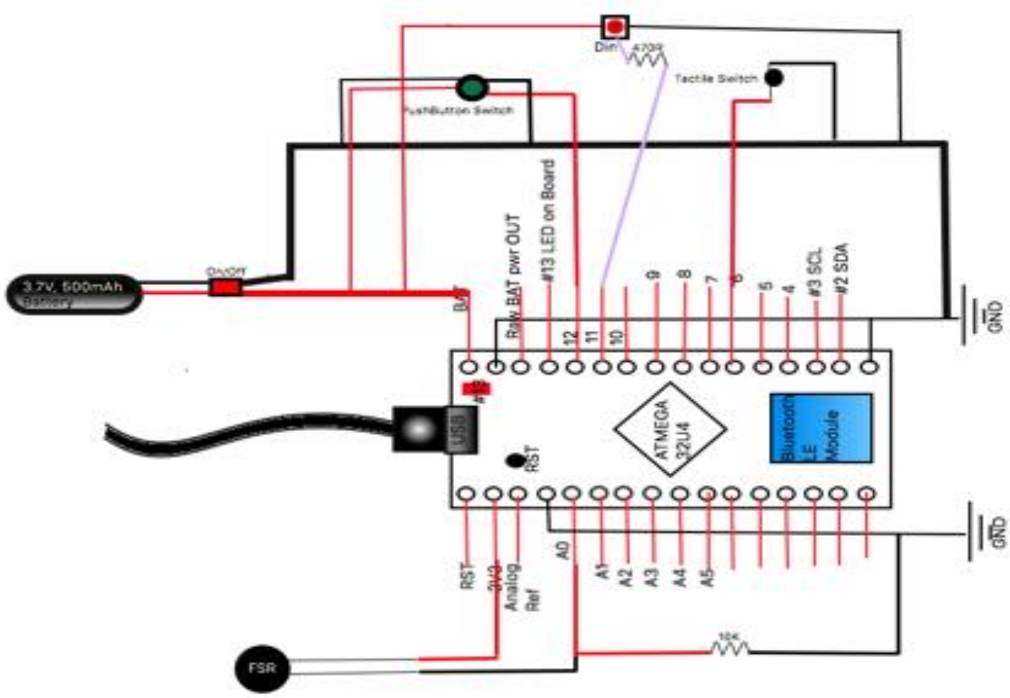


Figure 10: Smart Stylus Circuit diagram

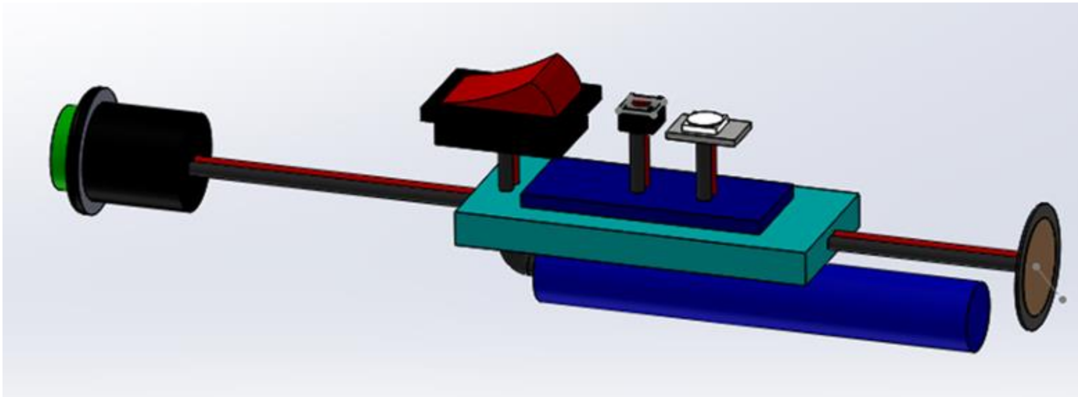


Figure 11: SolidWorks design of Smart Stylus interior layout

5.4.1 FSR Electrical Behavior

Special attention should be given to the FSR and its unique electrical behavior. The FSR circuit acts as a voltage divider, with voltage across R1 going in Analog input pin A0. More pressure causes the resistance of FSR to decrease, as shown in Figure 12, which in turn causes the voltage across R1 to increase. This change is read by the analog input pin A0 of the Bluefruit Micro LE.

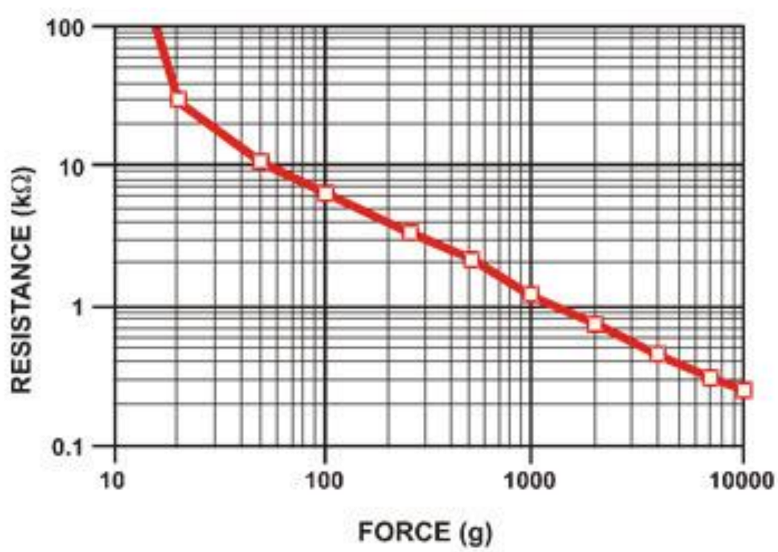


Figure 12: Force vs Resistance of FSR [6]

5.5 Software Design

All the processes that control the smart stylus will run on Bluefruit Micro LE microcontroller. The main process loop that is responsible for sending and receiving data is always running and will consume the vast majority of the microcontroller's power and resources. To ensure synchronized, real time communication, the loop must complete in no more than 20 ms.

5.5.1 High Level Design

Once the Smart Stylus is turned on using the ON/OFF switch, power will be supplied to all the components of the Stylus, and Bluetooth connection to the Raspberry pi will be established. The LED on the pen will show the default color selection of white. The smart stylus will now be ready to be used. As the user touches the Canvas, FSR will detect and measure the pressure and the data will be sent to the Canvas in real time. If the color wheel selection button is pressed, an event will be triggered, which will pause all the processes running on the microcontroller and inform the Raspberry Pi about the event. It will remain in pause mode until it receives a command from Raspberry Pi to resume all processes. The LED will now show the updated selected color.

The connection to Canvas will be maintained until the smart stylus is switched off. Communication between smart stylus and canvas will be continuous and in real time. Every reading should be sent to the canvas in no more than 20 ms. Figure 13 shows a flowchart which describes this process.

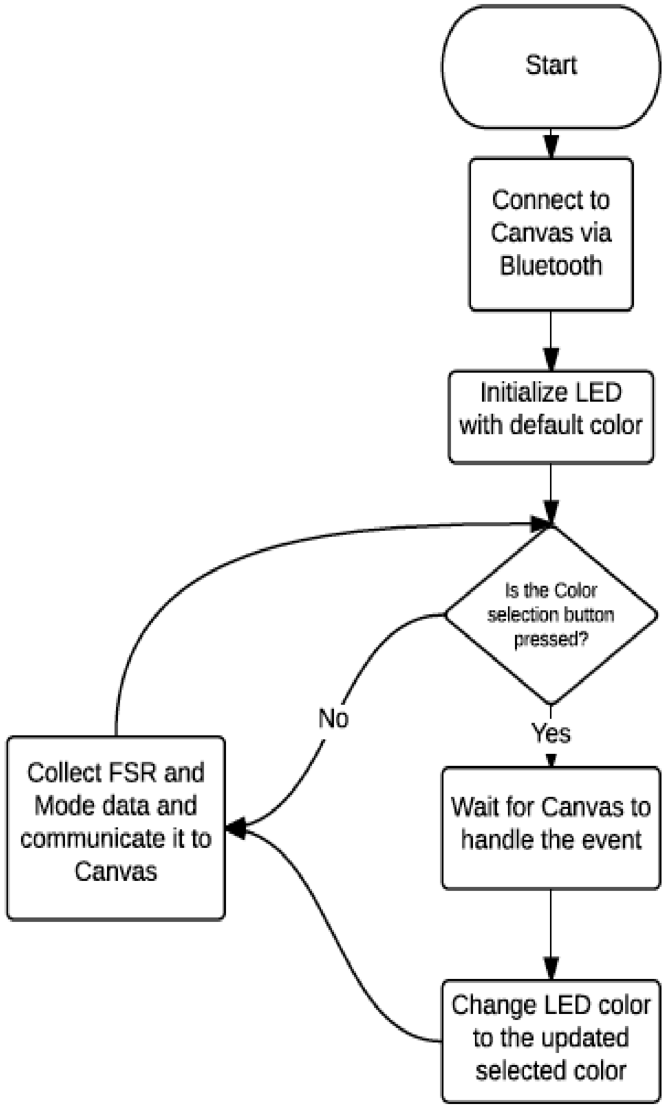


Figure 13: Flowchart of the Smart Stylus main process

5.6 Further Design Considerations

The design of the Smart Stylus above, being the prototype, will be very different from the final product. However, the final design based off this prototype model.

Future revisions of smart stylus will incorporate much more detailed functionalities such as Bluetooth connection status light and a flexible PCB board to allow the stylus chassis to be constructed smaller. This will be accomplished by designing own microcontroller and PCB. Additionally, future revisions of the Smart Stylus will include a rechargeable battery that can be recharged via a micro USB connection to the canvas.

6.0 LED Array

The LED array is a vital part of the Dot Light Canvas system. It is the very heart of the project, as it is responsible for providing the light that illuminates the canvas. Each LED included in the array represents one pixel, and each pixel's brightness and color must be individually controllable.

6.1 Physical Design

The LED array must adequately cover the interior of the 32" infrared touchscreen with LED lights. The array, its power supply and electronic circuit must also total no more 50mm in thickness so that it can be stored within the canvas chassis.

6.1.1 LED Matrix Design

The prototype Dot Light Canvas LED array consists of 24 strips of 42 individually controllable Adafruit NeoPixel LEDs [10] for a total of 1,008 LED lights, fulfilling requirement R93 from the *Functional Specification: The Dot Light Canvas* [1] document. To fill the interior of the 32" infrared touchscreen, the LED strips are vertically mounted on a perforated OSB board of the same size. The LED strips are spaced 4mm apart from one another, leaving 3mm of space between the edges of the screen and the first LED. Each strip has a power, ground and data-in channel which are routed to the back of the board to join the rest of the electric circuit, discussed in section 6.3.

6.2 Power Delivery

To fit within the canvas chassis, the power supply, bus bar, all wiring, microcontrollers and proto board circuits must be mounted to the back of the OSB board that holds the LED array. The components most not protrude more than 30mm from the back of the OSB to ensure that they do not come into contact with the chassis itself.

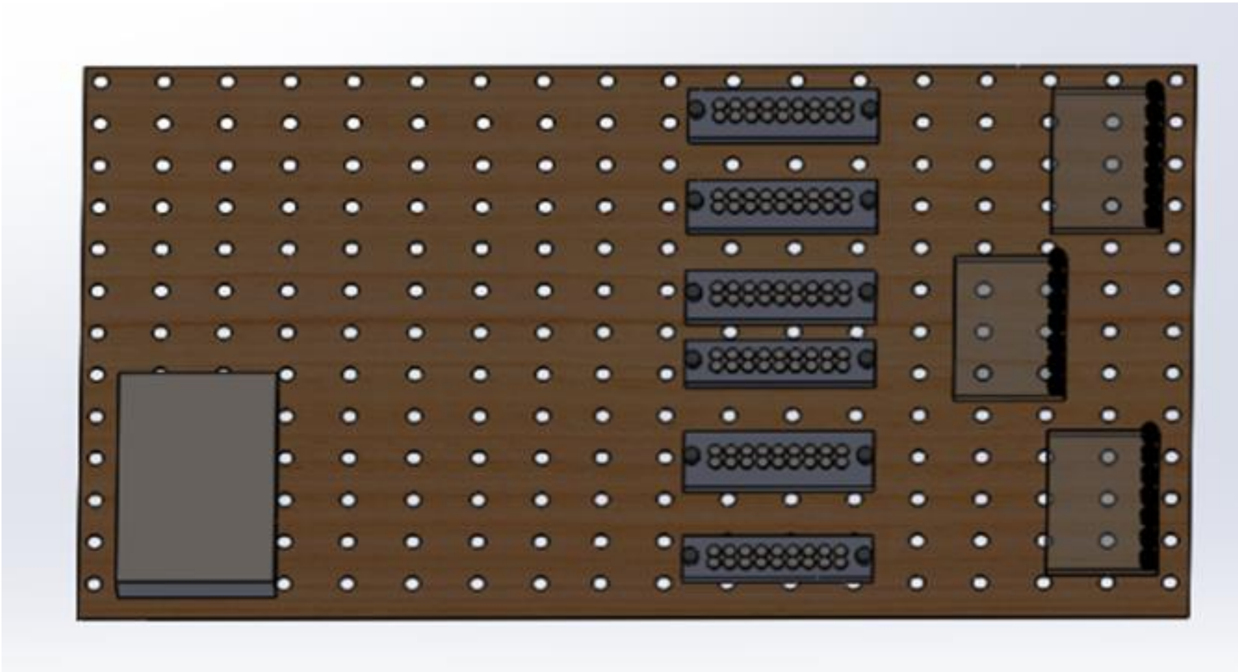


Figure 14: SolidWorks Design of the Power Delivery System

Figure 14 shows the layout of the power delivery system. The power supply is located at the leftmost side of the board. The bus system is located in the center and draws power from the power supply. The prototype boards, on which the circuits to control the LED lights are built, are located at the right of the board. Wires then wrap from the prototype boards to the flipside of the board, delivering the LEDs with power and data.

6.2.1 Power Specifications

As per requirement R97 in the document, *Functional Specification: The Dot Light Canvas* [1], each NeoPixel LED must operate at 5 volts and draws a maximum of 60mA of current when fully powered. As a result, a 5V DC power supply capable of providing up to 2.5 Amps of current per LED strip is required. Therefore, Art Tech has chosen 5V the Mean Well RSP-320-5 [11] to deliver power to the Dot Light Canvas, as it is capable of supplying up to 60Amps of total power at the correct voltage for the LEDs.

The power supply delivers power to three pairs of bus bars. Each pair of bus bars is able to deliver 20 Amps of current and is connected to 8 LED strips. The bus bars deliver the power to the prototype boards on which the LED array circuitry resides, and the bus bars must be used because a traditional prototype boards are unable to deliver the large amounts of current the LEDs require when fully powered.

6.3 Electronic Design

The LED matrix is controlled by three microcontrollers, each of which are responsible for eight LED strips. The microcontrollers The LED array is the most power hungry aspect of the Dot Light canvas system, and therefore requires a power supply and appropriate safety measures to operate as desired.

6.3.1 Safety Considerations

Due to the high level of current being used, certain safety precautions must be made to ensure both the safety of the user and the system. Firstly, protection of the LED lights of the prototype array is very important as they are one of the most costly components of the Dot Light Canvas system. A 20A fuse provides overcurrent protection to each bus bar and its array of LEDs, acting as a circuit breaker in the event of a power surge. If more current is flowing than the LEDs are capable of drawing, the fuse will blow, ensuring the LEDs are not ruined and the user remains safe from too much power.

A 1000uF capacitor has also been placed between the power line for each LED strip and ground for a total of 8000uF, which protects the LEDs from sudden changes in current that will occur when the user is painting.

Finally, a 470 ohm resistor is placed between the microcontroller and the data-in line to protect the delicate chips embedded in the LED lights.

To protect the user, the power supply is entirely housed within chassis of the canvas, and mounted to the back OSB board that holds the LED matrix. Users do not have access to any part of the power supply or circuit, with exception of the wall plug.

6.3.2 Electronic Circuit Design

The LED Array relies on three identical FadeCandy [12] microcontrollers to supply the LEDs with control data. Each LED Strip has a data-in channel connected to one of the microcontrollers, and the microcontroller itself is powered and controlled by a Raspberry Pi 2 [5] microcontroller.

In figure 15, a single block of the LED Array circuit is shown. Three such blocks exist, connected to one another in parallel. The blocks consist of their own power bus, fuse, microcontroller, capacitors and 8 sets of NeoPixel LED strips and their data lines.

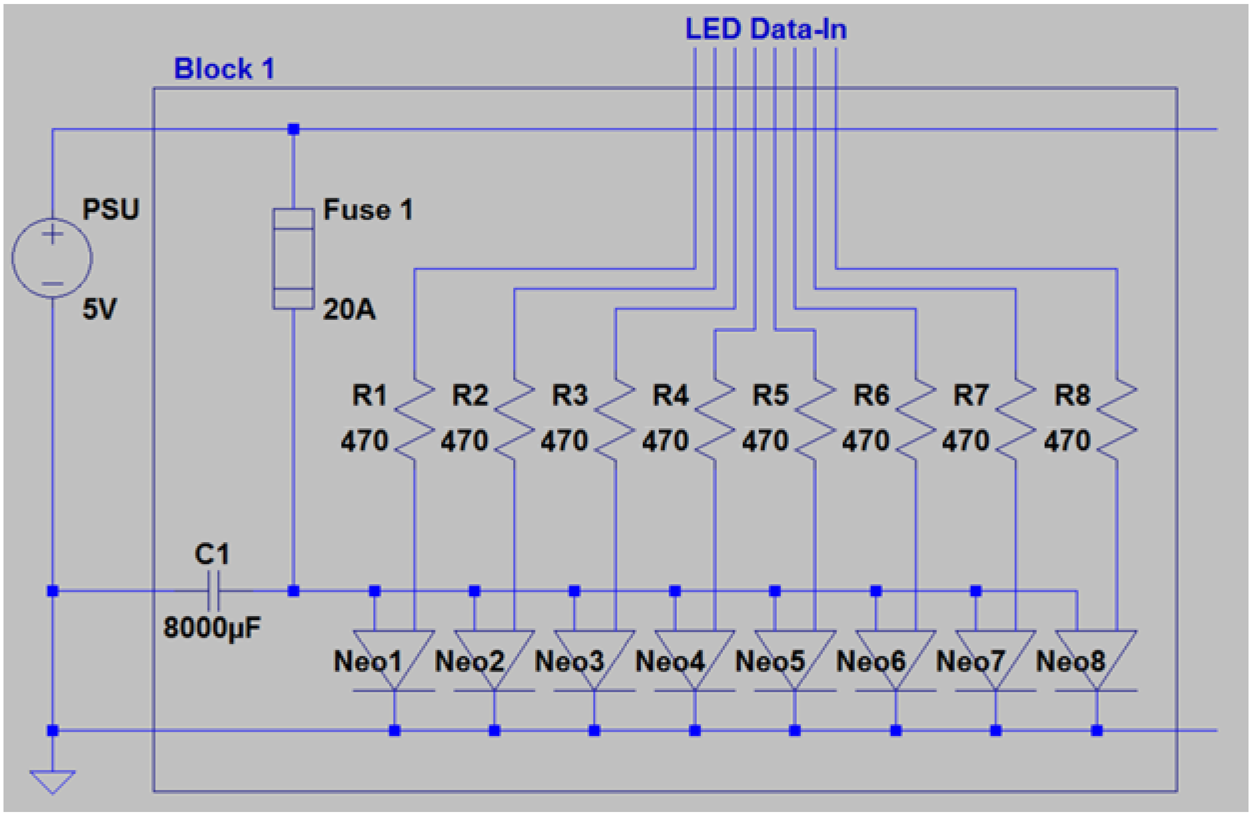


Figure 15: LT Spice Circuit Design for Block 1 of the LED Array

6.4 Software Design

The process that controls the LED Matrix will run on the Raspberry Pi 2 [5] microcontroller, and is responsible for ensuring that the LEDs light up at the correct brightness and intensity.

The main process loop that controls the LEDs is always running, and will consume the vast majority of the microcontroller's processing power and resources. To ensure that the user is given immediate feedback while painting, the loop must complete within 20ms.

6.4.1 High Level Design

When the canvas is turned on, the controller will initialize the LED array and default color and mode values. It will then read the data being received from the smart stylus, once every 20ms, fulfilling requirement R101 from the document, *Functional Specification: The Dot Light Canvas* [1].

With every read, the controller will check if the pressure sensor was pressed. If it was, it will read the location information being sent by the IR touchscreen. If a value is present, the controller knows that the pen has been pressed to the screen. It will then determine what mode the pen was in, and will calculate which LED is being written to, also determining which of the three FadeCandy [12] microcontrollers the Raspberry Pi 2 [5] will be communicating with.

If the smart stylus was in erase mode, the controller will clear the data from the current location the IR touchscreen was reporting. If the smart stylus was in color selection mode, it will bring up a color wheel on the canvas and wait for a selection to be made before writing the color choice back to the smart stylus. Finally, if the smart stylus was in write mode, the controller will calculate the color and intensity based on the values read from the smart stylus, and then command the correct FadeCandy [12] microcontroller to write the calculated value back to the LED at the location specified by the IR touchscreen. This process will repeat for as long as the canvas remains powered. The flowchart shown in figure 16 describes this process visually.

6.5 Further Design Considerations

The prototype LED Array described thus far has a much different design than the final product. Future revisions of the Dot Light Canvas will have a higher resolution, and will use a single microcontroller to control all aspects of the canvas, including LEDs. The LED array will also be consist of a single matrix on PCB as opposed to the separate strips used in the prototype, and power will be delivered from a single bus bar instead of the three sets currently used. Optimizations will also be made to make the array lighter and smaller.

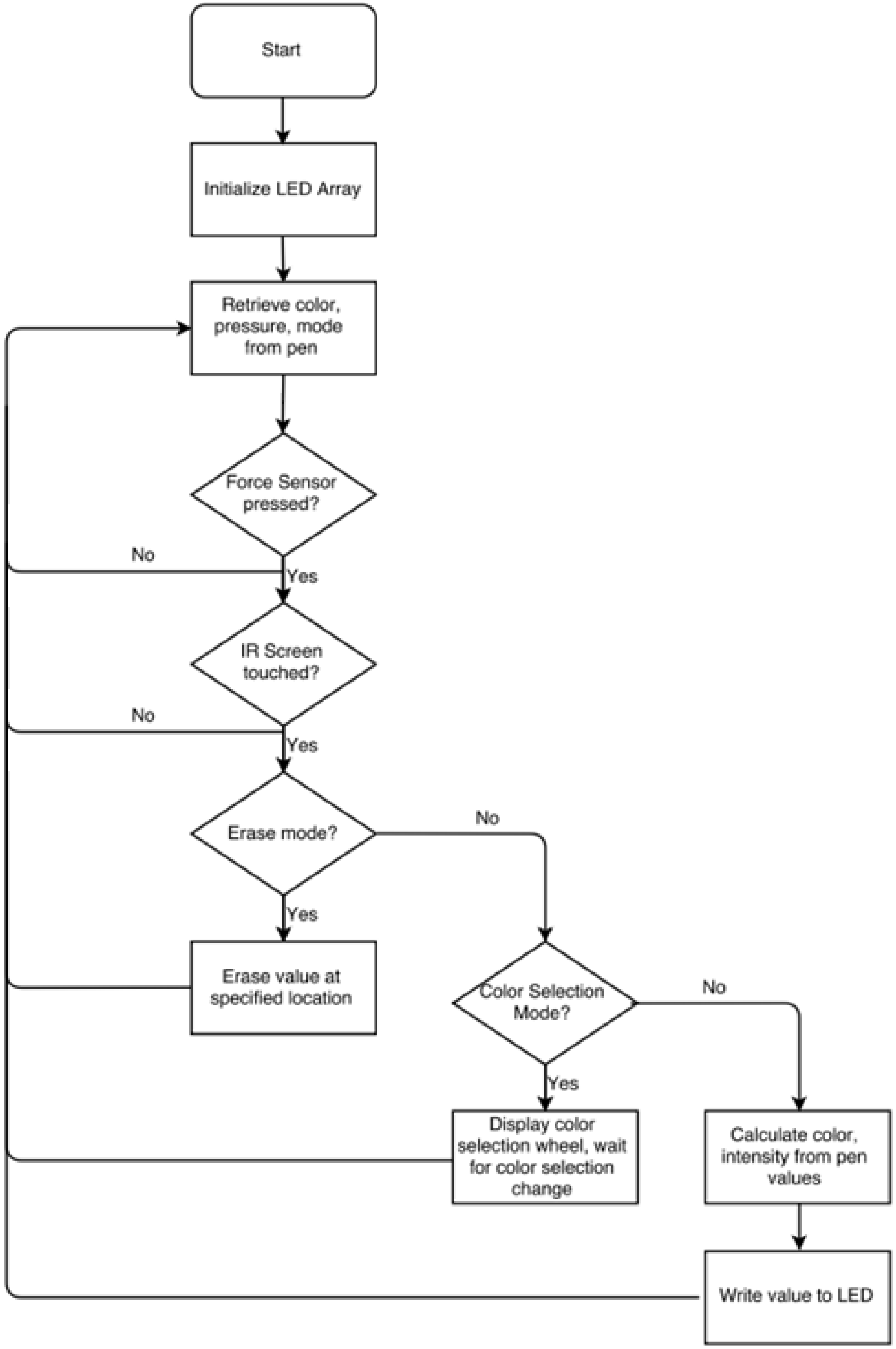


Figure 16: Flowchart of LED Array Process

7.0 System Test Plan

The prototype Dot Light Canvas system will undergo a series of testing processes before it is deemed to be fully functional. Firstly, unit tests will be conducted. If any tests should be failed, the offending unit will be revised and tested again. After the success of all unit test cases, the system will be tested as a whole, following the same procedures as above.

Types of tests include the following:

- F: Functional
- E: Electrical
- M: Mechanical

7.1 Unit Test Plan

Unit test plans are independent of one another and can be tested concurrently, without the need for other parts of the system to be present. The Dot Light Canvas has two main units; the LED Array and the Smart Stylus. Their test cases are outlined in table 3.

Table 3: Unit Test Cases

Test #	Unit	Type	Test Case	Expected Outcome	Pass Fail	Comments
1	Smart Stylus	F	The power button is switched to the 'on' state	The smart stylus is powered on, the color indication LED turns on with the default color white, to indicate power, Bluetooth communication is enabled		
2	Smart Stylus	F	The power button is switched to 'off' state	The smart stylus is powered off, the color indication LED turns off as a result		
3	Smart Stylus	F	The tip of the stylus is pressed to a surface	The stylus microcontroller correctly captures and reports the pressure data from		

Test #	Unit	Type	Test Case	Expected Outcome	Pass Fail	Comments
				the pressure sensitive tip		
4	Smart Stylus	F	The erase button is depressed	The stylus microcontroller correctly reports the 'erase' mode, indicated by a flashing white in the color indicator LED		
5	Smart Stylus	F	The erase button is not depressed	The microcontroller correctly indicates the smart stylus is not in 'erase' mode, indicated by a solid (non-flashing) LED		
6	Smart Stylus	F	The tactile color selector button is pressed	The microcontroller correctly indicates the smart stylus is requesting a color selection event, indicated by a continuously changing color by the color indicator LED		
7	Smart Stylus	M	The smart stylus detects up to 20lb of pressure	After 20 pounds of pressure have been applied, the microcontroller reports a constant pressure setting		
8	Smart Stylus	M	The smart stylus' width and height are measured	The smart measures no more than 30mm in diameter and 190mm in height		
9	Smart Stylus	E	The operational voltage is measured	The smart stylus operates at 3.7V		

Test #	Unit	Type	Test Case	Expected Outcome	Pass Fail	Comments
10	LED Array	F	An LED is supplied with power, then given color and intensity information	The correct LED changes to the color provided at the intensity indicated		
11	LED Array	F	All LEDs in a control block are supplied with power	All LEDs in the block are illuminated at full intensity, no flickering of the LEDs occurs at full intensity		
12	LED Array	E	An LED is fully powered	A single led draws approximately 60mA of current at max intensity		
13	LED Array	E	All LEDs are fully powered	The system draws no more than 60A of current		
14	LED Array	E	The operational voltage is measured	The LEDs operate at 5V		

7.2 System Test Plan

Once all unit test cases have been passed successfully, the system will be tested as a whole, following the test cases outlined in table 4.

Table 4: System Test Cases

Test #	Type	Test Case	Expected Outcome	Pass Fail	Comments
1	F	The canvas is plugged into a wall plug	The canvas receives power, the LEDs display a splash image for a small length of time to indicate power is on		
2	F	The smart stylus is powered on	The smart stylus automatically connects to the canvas (if powered) wirelessly though the Bluetooth connection		
3	F	The canvas touchscreen is touched by something other than the smart stylus tip	No action takes place		
4	F	The canvas touchscreen is touched by the smart stylus' pressure sensitive tip while in paint mode	The color indicated on the smart stylus is written to the LED on the canvas at the location of the press, with a brightness that corresponds to the pressure applied		
5	F	The canvas touchscreen is touched by the smart stylus' pressure sensitive tip while in erase mode	The LED on the canvas at the location of the press is turned off		

Test #	Type	Test Case	Expected Outcome	Pass Fail	Comments
6	F	The smart stylus' color selection tactile button is pressed while the canvas is not in color selection mode	The canvas replaces the current painting with a color wheel		
7	F	The smart stylus' color selection tactile button is pressed while the canvas is in color selection mode	The canvas dismisses the color wheel, the smart stylus maintains the previous color selection		
8	F	The smart stylus is touched to the touchscreen at the location of a color in the color wheel	The canvas dismisses the color wheel, the smart stylus switches colors to the color that was touched		
9	M	The canvas is checked for moving parts	The canvas has no moving exterior parts except for the power plug		

8.0 Safety

Art Tech understands the importance of safety. We has made every effort to ensure the safety of both the users and the equipment. The Smart Stylus is constructed of PLA, a thermoplastic material that is a poor conductor of electricity. This ensures that the user is not exposed to any amount of power from the internal components. The interior electronic components of the Smart Stylus will also remain hidden behind the exterior shell preventing the user from having access to them. Furthermore, only electrical components that were both safe for use and could accomplish the desired function were chosen. These components choices ensure that excess energy is not drawn, so that the risk for the user is minimized. The Smart Stylus also has a power button that will turn the stylus power off.

The Acrylic glass has water resistant properties and is to prevent any accidental liquid spillage from causing electrical problems with the canvas. In the improbable case where liquid does infiltrate and affect the electrical components, the outer wooden chassis will prevent electrical harm to the user. In case of an emergency a power button has been installed, which turns the unit off. Additionally, as discussed in section 6.3.1, fuses have been installed in the LED Array circuit to ensure overcurrent protection, capacitors are used to protect the components from damage, and all parts that conduct electricity are safely sealed within the canvas chassis.

9.0 Sustainability

Art Tech is to design the Dot Light Canvas with sustainability in mind. To the best of our ability we have attempted to stay conserve the consumption of non-renewable resources and improved our design through social, economic and ecological aspects.

The exterior of the Smart Stylus for the Dot light Canvas will be manufactured using a 3D printer with Polylactic Acid (PLA) filament. Being a biodegradable thermoplastic, PLA is the most environmentally friendly filament in 3D printing. The material properties possessed by PLA filament allow for a more cost effective manufacturing process .PLA consumes less energy and power, because of its lower temperature threshold of 160 – 220 degrees Celsius; as compared to petro-chemical based plastic filaments such as Acrylonitrile Butadiene Styrene (ABS) which possess a temperature threshold of 210 – 250 degrees Celsius.

The Smart Stylus is to be designed with a power switch to conserve energy with the stylus is not in operation. The design of the Smart Stylus will ensure each individual component can be disassembled and salvaged after the lifecycle of the Smart Stylus

The chassis of the canvas is spare cedar wood from a home renovation project and like the Smart Stylus the chassis and interior canvas will be engineered so as much as possible is salvageable. The acrylic glass is easily removable from the infrared touchscreen and both can be recycled as neither will be chemically altered. The cloth layering the back side of the glass can be removed and used as fabric material elsewhere. Many of the electronic components were assembled with reusability in mind and after the lifecycle of the Dot Light Canvas they will be taken apart and utilized for personal projects. The Canvas will be designed will a power button to conserve energy when not in use.

Art Tech has obtained as much materials and components locally to reduce the consumption of fossil fuels, extra packaging and other resources associated with shipping components across countries. Purchasing materials and components locally will also improve the economy of the local community.

10.0 Conclusion

The design described in this document realizes the functional specifications of the Dot Light Canvas, as outlined in the document, *Functional Specification: The Dot Light Canvas* [1]. Throughout the construction of the Dot Light Canvas prototype, the Art Tech team will adhere as closely as possible to the design decisions within this document. Furthermore, the completed prototype will be tested against the test plan outlined in section 7.

With a clear and concise design now in place, it is the hope of the Art Tech team to create a high quality, functional that will inspire interest in future revisions of the product. The prototype has a projected completion date of December 18th.

11.0 Glossary

- ABS - Acrylonitrile Butadiene Styrene, a petro-chemical based plastic filament
- Adafruit – Online vendor that designs and sells a variety of electronic components, including the NeoPixel LED strips and their controllers
- Art Tech – Company that proposed the Dot Light Canvas. Includes the four founding members, Zachary Cochrane, Dana Sy, Bhavit Sharma, and Aman Shoker
- Bluefruit – Bluetooth microcontroller designed and sold by Adafruit, used to control the Smart Stylus input and communication with the Dot Light Canvas
- C2C – the Cradle to Cradle design approach is the view that a system should be designed such that all components can be reused or recycled in one way or another at the end of the systems lifespan
- Dot Light Canvas – A proposed LED Painting system that allows users to 'paint with light'. Consists of an array of LED's behind an IR touch screen, controlled by a smart stylus.
- FadeCandy – NeoPixel Microcontroller designed and sold by Adafruit, used to control up to 512 individual LEDs in 8 strips of 64 each
- IR Touchscreen – Infrared touch screen. Uses infrared lasers coupled with sensors to detect where a touch has been made.
- LED – Light Emitting Diode. A light source consisting of a p-n diode that emits light when activated. Known for its intense luminosity and vibrant color.
- MDF – Medium Density Fiberboard, used for constructing the canvas chassis
- NeoPixel – Programmable RGB LED designed and sold by Adafruit
- PLA – Polylactic Acid Filament, a biodegradable plastic commonly used as a source of 3D printing material.
- Raspberry Pi 2 – General purpose microcontroller designed and sold by the Raspberry Pi Foundation which will be used to control the Dot Light Canvas
- RGB – An additive color model which adds Red, green and blue hues together of varying intensity to produce a large number of different colors.
- Smart Stylus – The device that controls the Dot Light Canvas. A stylus that, when applied to the canvas, turns the LED's behind it on and off, depending on its mode. Has color controls and the ability to switch modes between paint and erase built right in.

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