Interactive Electroluminescent Bus Route Display

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ABSTRACT
In this project, our team developed a new bus route display that involves an interactive electroluminescent technology. Our approach for the development of an interactive electroluminescent bus route display included purchasing the needed EL material to fabricate the display and developing software which tracks buses along bus routes on the Georgia Tech campus. The integration of the display and software presents a real-time bus route display that can provide a ubiquitous use across campus. This project gave us insight into potential uses of the electroluminescent technology and in particular, how it can be used as a ubiquitous display.

Categories and Subject Descriptors

General Terms
Design, Economics, Experimentation, Human Factors, Ubiquitous Computing.

Keywords
Electroluminescent

1. INTRODUCTION
Electroluminescence (EL) is the production of visible light by a substance exposed to an oscillating electric field without high thermal energy generation. In particular, phosphor is such a substance that demonstrates the phenomenon of elctroluminescence (not to be confused with the chemical element Phosphorus, which emits light due to chemiluminescence**)**. In particular, EL displays provide a technology where brightness, speed, high contrast, a wide viewing angle and robustness are important. These displays can be produced by layering an electroluminescent material between two conductors. Accordingly, when the electroluminescent material is in the presence of an oscillating electric field it emits radiation in the form of visible light.

Currently at the Georgia Institute of Technology, the Stinger bus stops provide “time until arrival” information. This information can be helpful, but not very accurate in relaying location information to the user. However, adding an EL map with interactive touch input that displays the current location of the buses would provide more accurate information in a visual format which clearly communicates spatial relationships.

2. PREVIOUS/RELATED WORK
Electroluminescent material is used in several products as an innovative solution to create designs which feature areas of lighted material with dynamically controlled luminance values. In advertising, poster images have areas masked to allow lighting to be designed and animated. In cars, EL material is used in dashboard displays for illuminating gauges. It is also used in materials wrapped on car body surfaces to create engaging visual effects. In car windows, decals with electroluminescent material display animated light designs. In a poster format, EL surfaces are combined with masking materials to design layouts. Featured in clothing, electroluminescent material is found in t-shirts, shoes, and fashion design.

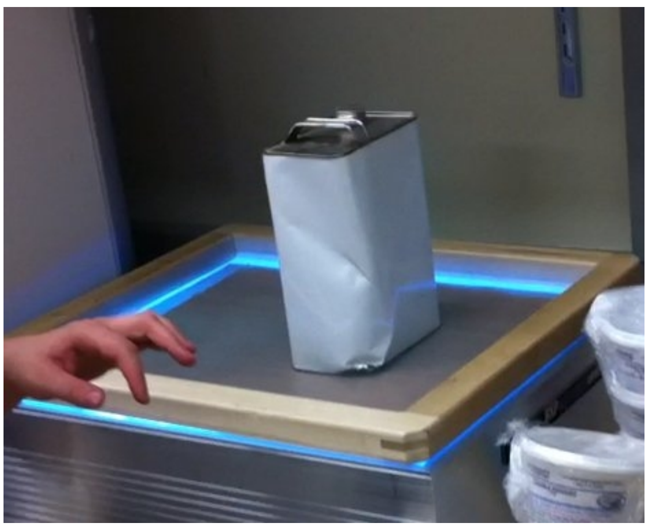
3. RESEARCH
Our project consisted of two sections that together would create the EL bus route display: the printing of the EL display and the software to gather information and control the lighting of the EL sections.

3.1 Electroluminescent Printing
The printing process begins with making the screens. Using an 18 x 22 inch blank screen for silk screen printing, photo emulsion is applied to the screen with a custom bar which allows for loading emulsion and a smooth and even

Figure 1: Applying photo emulsion to silk screen

application of the material. After application, the screen is left to dry for approximately 1 - 2 hours.

A positive of the desired image is printed on a clear transparency with an ink jet printer. This transparency is placed on a UV light table with the dried screen placed on top and even pressure is applied to the surface for five minutes. After the photo emulsion has been exposed to UV, the screen is washed out to remove the emulsion from the exposed positive image area. This leaves photo emulsion on the screen blocking areas where ink will not be printed and an area which is free of emulsion (not blocked) for printing. The exposed area matches the positive image from the original ink jet transparency. Because the screen is now wet from washing out the exposed area, the screen must be left to dry for approximately 2 - 3 hours before printing. Images here show a test performed prior to the printing of the bus map.



The screens are then registered to print using a four-color printing station designed for CMYK color silk screen printing (individual screens for printing cyan, magenta, yellow, and black inks). In this case, three of the four arms in the station are used to register each screen for printing electroluminescent, dielectric, and conductive ink layers. Proper registration of the screens is key to aligning each layer of ink material properly when printing on the Mylar surface.

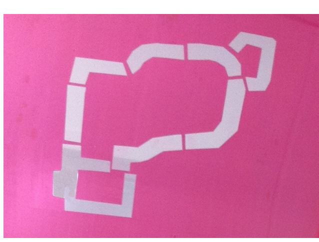


Figure 3: Screen with phosphor design

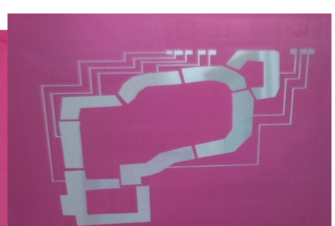


Figure 4: Screen with dielectric design

EL displays can be printed either from front to back or vice versa. From the materials that we acquired from DuPont Microcircuit Materials (EL phosphor and dielectric) and Bayview Optics (Mylar with Indium tin oxide), we began from the front with the layer of Mylar with an ITO coating. On this we screen printed the EL phosphor into a pattern of the campus bus route, split into eight segments. Next came the dielectric layer which covered the phosphor and prevented the conductive ink leads that trailed to the top of the display from shorting on the ITO. This layer is used to create the proper capacitive environment for the phosphor. Lastly, we printed the conductive ink on top of the dielectric, both the route and the leads. Each time a layer was printed, we would dry the layer using a mobile heater.

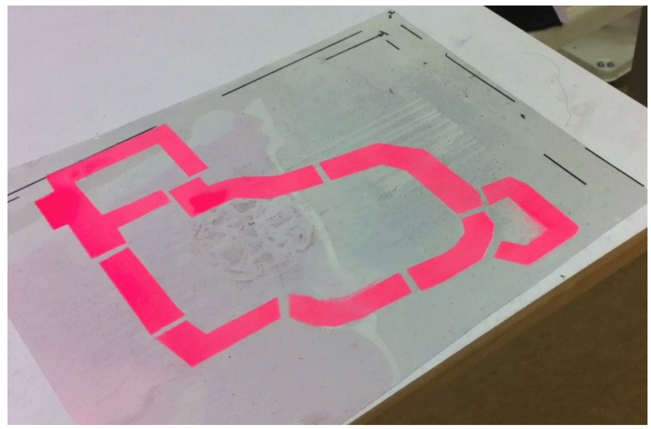


Figure 3: Printed EL phosphor

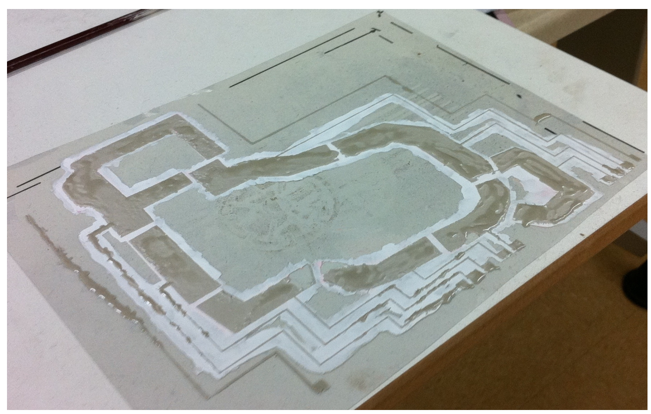


Figure 4: Printed dielectric (white) and conductive ink (silver)

3.2 Software

In the most general sense, the software for the Interactive Electroluminescent Bus Route Display was developed using Java and the Java Development Kit. Java allowed for intuitive development and integration with the Arduino board. In particular Java lent itself the ability to create an interface that would allow us to make calls to be performed on the Arduino board. Java also provided a JSON parser which we were able to use in order to parse the real-time bus locations.

We created the bus route by configuring sixteen red and blue bus stops around the Georgia Tech campus with latitudinal and longitudinal points. We grouped every two bus stops together, giving us eight total bus stop segments on the electroluminescent display. This grouping was captured by creating a "rectangle" where the latitude and longitude of the top left corner and the bottom right corner was recorded. This "rectangle" encompasses two bus stops creating our segments.

The bus location data is gathered real-time and parsed to determine the latitude/longitude of each red and blue bus. The current bus location data is provided by the GTMob group in JSON format. The bus data provided in JSON format includes: a unique identifier for each bus, the color of the bus, the latitude and longitude position of the bus, and its current speed. The bus locations are updated every thirty seconds with the bus route display updated accordingly.

In order to determine if a red or blue bus is within a segment (bus stop "rectangle") on the display, we test the parsed bus location against that of the bus stop segment. If any of the buses are currently within any segment, we write to a specific port on the Arduino board that is associated with each segment. The Arduino is interfaced with the El Escudo, an Arduino shield board, which in turn sends current to an associated lead that results in lighting up a specific bus stop along the bus route.

The computer interfaces with the Arduino by sending data packets over UART. These data packets are 8 bits wide. The first bit in the packet is the analog/digital bit, which chooses what mode the pin is in. The next bit is the read/write bit, which sets the read write mode. The third bit is the value bit. This bit is what will be written to the pin if in write mode. The last 5 bits are the address of the pin to be acted on.

4. DISCUSSION

The point of our project was to achieve Mark Weiser's vision of "calm" computing for locating buses along a particular route while standing at a bus stop. Our EL map will be displayed at bus stops just like any other map, waiting in the periphery. However, once the user decides it needs the information, the display has it available.

Electroluminescent phosphor was chosen for a few simple reasons. First, due to the capacitive nature of the EL phosphor, the power consumption for the display is very low since the current draw is minimal. Another great feature of EL displays is they are very thin due to the printing process and the capacitive requirements. An EL display is about the thickness of a few sheets of paper.

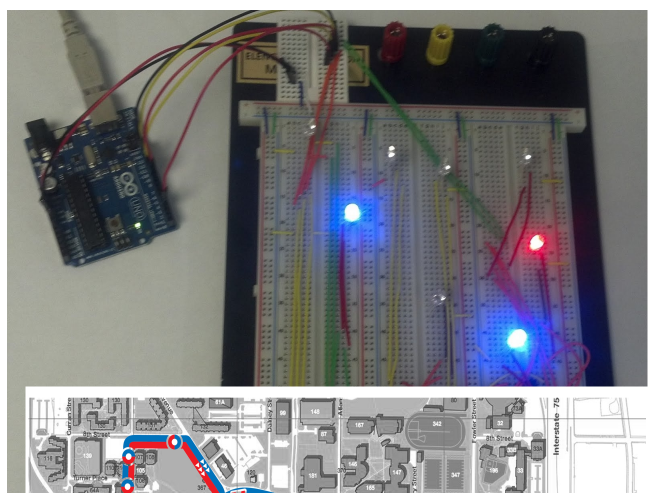
The drawback of electroluminescent displays is the lifespan of the display. The brightness of the displays depend on the voltage and frequency of the power supplied to them. Voltage and frequency also attribute to how long the screen will last, which averages at about 2 years of constant lighting. Therefore, a screen will last longer in a dark environment where a less illuminating output will suffice than in a bright setting where the voltage and frequency may need to be increased to achieve appropriate brightness.

One of the limitations that we had in our experimentation with electroluminescent displays was the number of EL segments that could be controlled by the El Escudo. This Arduino shield contained only eight AC outputs to power the EL, therefore, our design was limited to only eight areas where the bus could be located.

Throughout this project, we learned many things through our hands on research with the electroluminescent technology. When starting this project, we had never worked with electroluminescent displays before so we began experimenting with pre-made materials. Once we began to print we realized that the process for making EL displays was more precise than expected and were able to perform on our first attempt.

Firstly, each material that is screen printed needs to be applied in thin and even layers. Failure in one or both of these areas will compromise the display and lead to uneven light distribution, only small areas lighting, or no lighting at all. This could have been avoided if we were more experienced in screen printing as our second attempt was much more successful.

Another setback in our production of the displays was our inability to accurately control the drying environment on the layers. The heater that we had access to did not have a temperature control and would achieve levels in excess of 700 degrees Fahrenheit, while the drying should have occurred in the mid 300's. The over heating of the material led to the dielectric and phosphor cracking and peeling away from the ITO. Drying using a controlled heater or oven would have produced far superior results.



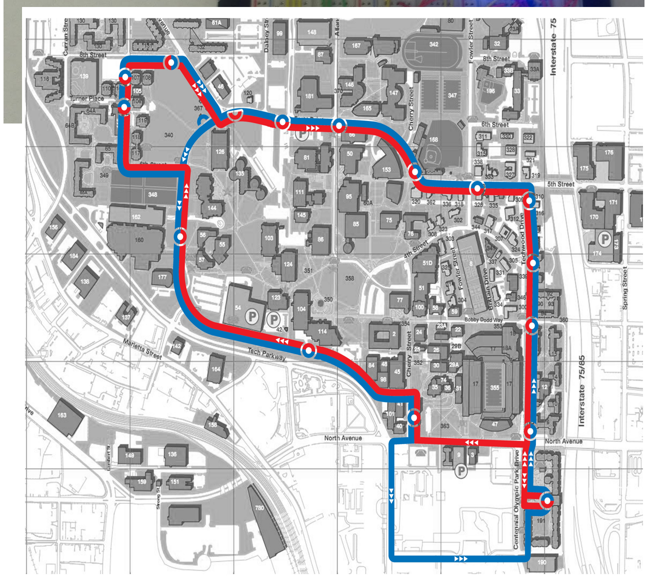


Figure 6: Bus route map

An unsuspecting discovery happened in our second attempt at printing. After we dried all the layers and applied voltage to the ITO and conductive ink. We realized that the layer of conductive ink could be manipulated with the lead and thinned in areas where the lead was dragged. These thinner areas of conductive ink provided bright spots in the illuminating phosphor, which was in effect drawing light in our display as shown in Figure 9.

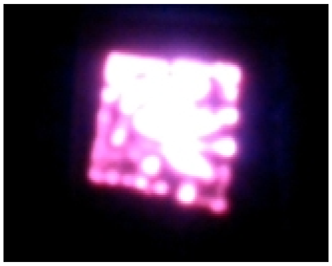


Figure 7: Drawing in EL display

Due to our printing process going awry we were unable to connect the EL Escudo. Therefore, we demonstrated the control software using an Arduino to interface between the computer and a makeshift display. The Arduino was connected to a Texas Instruments TLC 5940 constant current PWM chip. This chip was then connected to 8 RGB LEDs to show the current red and blue bus locations. On top of the breadboard that held the hardware, a paper map of the bus route was laid with the LEDs lighting up near the appropriate areas of the map.

5. FUTURE WORK

From the knowledge that we have gained this semester, we believe that even though screen print EL displays can go wrong in several ways, these mistakes can be avoided to create incredibly customizable electroluminescent displays. Moving on, we would need to create a working EL display with the bus stops. Also, we would create a touch sensing interface using the Arduino to allow the user to chose a specific bus route to display. This can be done several different ways including tactile buttons, or resistive or capacitive touch sensing.

Another thing that should be improved from our project is the number of AC outputs to control the EL segments. In our project we only had eight on the El Escudo, yet there were twice that many bus stops that we had to cover. Doubling the number of AC ports would help, but increasing the number further could allow us to give much more precise location information. The best way to do this would be to design a PCB, that will give us the ability to have as many AC ports as we need.

Other ideas that we considered after this experience with the EL displays were an EL Etch A Sketch where you could draw lines of light into a dark background. Another idea that was given to us by a student at our presentation was using these displays in a children's book to light up certain parts of the page, a variation on pop-up books.

6. CONCLUSION

In this paper, we have described in depth the process to screen print electroluminescent displays. We have also described our software implementation to gather location information about the Stinger buses and relay it to the user through the EL display. Many things have been learned through these processes about both the electroluminescent displays and how they are made and using the Arduino and serial ports on the computer to communicate the desired information. Screen printing EL displays is excellent for applications that don't require a large number of independently controllable sections in a small area and where the lifespan of the application can be just a few years.

7. ACKNOWLEDGMENTS

Our thanks to Clint Zeagler for allowing us to use some of his conductive ink and teaching us how to screen print. We would also like to thank Caleb Southern for giving us his Mylar source in Maine. And finally, to Scott Gilliland who introduced us to electroluminescent displays and gave us the idea for the project.

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Appendix

Touch Electroluminescent Displays Using Conductive Ink

Description of previous research in the area

Over the year, there has been a fair amount of research done in the area of touch sensing electroluminescent displays. We have seen the emergence of ubiquitous use of EL displays and in particular, the capability for touch interactivity in these displays. This research has led to a number of patents on specific technologies. These touch sensing technologies will provide the basis for our project implementation.

One implementation that includes a touch-sensitive technology in EL displays is a touch panel device that is used for data entry on a computer. The EL panel display is constructed in the following way: a transparent conductive film is affixed over the display. A user can touch the film at particular points on the display which capacitively couples together current scanning voltages, thereby, providing input for the display. This input voltage to the display results in the activating of the EL (i.e. lighting up).

Another technology involving EL displays that includes touch-ready technology is a design consisting of a touch activated EL display that uses pressure to bridge a gap in the material. Here the display consists of several layers. These layers include a "transparent electrode deposited onto the flexible transparent substrate, a phosphor layer over the transparent electrode, a dielectric layer over the phosphor layer, and a second electrode, which together form a lamp." The novel design for this implementation includes a third electrode that is separated from the second electrode by a insulating spacer leaving an open region. This is configured in a manner that allows for contact between these two electrodes when pressure is applied to the incorporated substrate. This design allows for further interactive points by employing additional electrodes that are separated by the insulating spacer from the previous electrode (a third electrode separated from the second electrode, a fourth electrode separated from the third electrode, etc). This configuration allows for selectively energizing regions of the display.

A final touch-sensitive EL display design includes the integration of resistive touch screen technology into the design. The EL display is located on one side of a substrate while the touch screen is placed on the opposite side of the substrate. The substrate consist of a transistor switching matrix and a light emitting layer. These components when used together form an active electroluminescent display matrix. The light is emitted through the transparent substrate to the active touch screen.

Description of what your group plans to do for the project (and why the work matters)

This project is a proof of concept for creating a electroluminescent display with touch input through the use of conductive ink screen printed on the transparent surface of the EL panel. This design combines two technologies in a novel way to produce an interactive display. The conductive ink will be sparse enough to allow light to pass through. It will consist of two lead wires printed on the surface (possibly for each EL segment). These wires will be part of a DC circuit that will use human skin to bridge the gap. The electronics for sensing will be interfaced using an Arduino that will control the EL segments to light the display in particular areas.

A number of design concepts incorporating interactivity have been discussed. These include the following:

<u>Concept One</u>

Interactive Display at Common Public Waiting Area.

This can display bus location, street names, and possibly can be used for interactive advertising. It has the potential to be great for public areas because it's relatively cheap in case it needs to be replaced and requires little power. EL lighting is already used in outdoor advertising and displays, it would be simple to integrate pre-existing EL lighting into interactive bus stop areas or information signs in an urban setting. It can also use ubiquitous features like bus tracking.

Concept Two

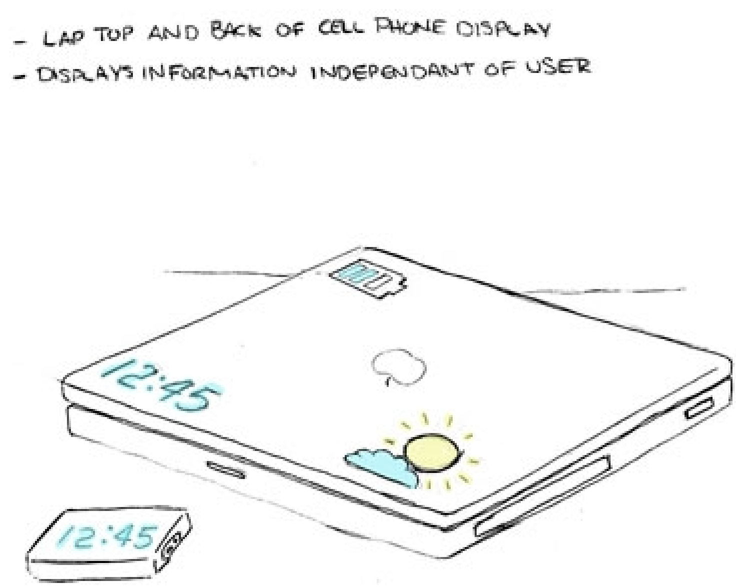
Interactive Surface in Children's Toys

This design is safe and may be used as a learning tool. The EL life cycle fits the product life cycle making it a good complement to the toys. Electroluminescent material can be incorporated into the product design which is safe for use by children. Because EL material has a life-span of approximately one year, it's inclusion in children's products matches the normal usage pattern for toys designed for 3-5 year old children. EL material provides an alternative solution for materials which emit light in these products.

Concept Three

Information Display for Mobile Devices / Computers

This design displays information independent of the user. Because of it's narrow height dimensions, electroluminescent material can be included in products which enhance existing products. In this example, a skin or shell has been created to fit to the surface of a laptop computer or mobile device. The shell has been designed to allow for the display of information which is dynamically driven by data taken from the computing devices. This data could provide current information about battery usage, status of files, weather updates and any other types of data which are not normally accessible without accessing the device or computer.

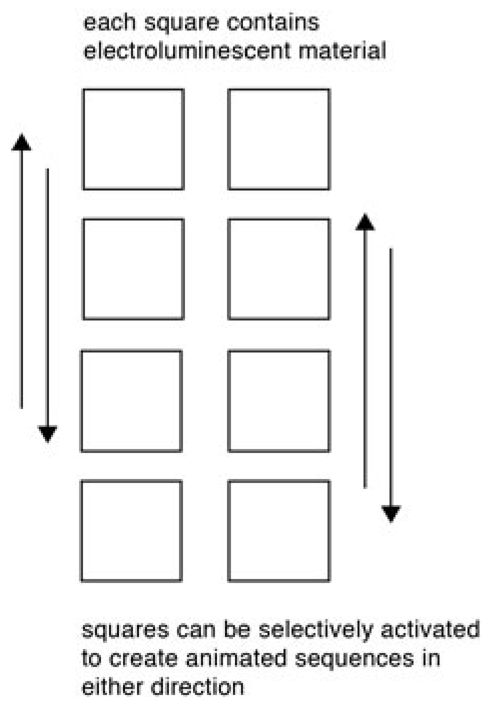


Concept Four

Interactive Display of Information in Retail Setting

This design can show pricing and available sizes as well as branding/advertising. This type of display could solve the issue with the customer shuffling through clothes to find the price and size of the item. It is also a more elegant way to depict sales and other information perhaps in a higher end store while also having the ability to show the store name or nothing at all.

<u>Concept Five</u>



Two-Person Game Board

In this concept, two players can send simple animated shapes back and forth by using rectangular tiles made from electroluminescent material. The board can be designed so that it only activates when two people are using the surface. It simulates a simple version of the game Pong, allowing the user to give input into the system in order to “hit” the ball back and forth. This game demonstrates the possible interactivity incorporated into an EL display.

<u>Concept Six</u>

Original Simon

EL Simon

Using electroluminescent material, an updated version of the electronic game Simon can be created. Interactivity will be similar to the original game, allowing for activation of lighted areas by touch. Blinking patterns of the pad lighted by electroluminescent material can be programmed, sequenced, and repeated using the Arduino.

Group Members and their Roles

Project Team:

Chris Bayruns - CS, Lead Arduino coder
Spencer Border - CS, Supporting with code and touch sense fabrication
Fred Leighton - ID (DM), Supporting with design and touch sense fabrication
Patrick Mize - CS, Lead on touch sense fabrication
Patricia Tait - ID, Lead Designer

Resources you may need (in terms of hardware, software, etc)

EL tape, wire, and surfaces (pre-fabricated)
EL Phosphor from DuPont
Mylar with ITO
Conductive ink
Arduino Uno
El Escudo
Wires

Timeline

October 25 - 31

1. Test components and system, Identify possible future technical issues

November 1 - 16

[14] Create designs for the EL phosphor and the conductive ink
[15] Fabricate an early prototype of the project, make sure we can do this before the EL phosphor arrives
[16] Integrate Arduino capabilities into design implementation

November 17 - 23

1. Screen print the final prototype with the acquired EL phosphor
2. Troubleshoot (quality control), Revise, Complete deliverable

Grading Criteria - What are the goals or deliverables of this project that you think we should grade you by

Concept

We are providing a novel proof of concept to be used with electroluminescent technologies. We believe that this concept can provide incentive for further research in this particular area.

Technical

The technical goal of this project is to develop a working system which incorporates an Arduino controller, electrical connections, and electroluminescent displays in existing forms (tape, wire, surfaces) or through the fabrication of materials (EL ink, conductive ink, etc.). Technical specifications will be detailed and described in documentation as part of the final set of deliverables.

Design

Design goals are to create a product prototype; a tangible, usable, interactive object featuring the functions outlined in the chosen concept. Design will seek to to address issues of physical ergonomics and aesthetics.

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