ECE 445

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Team 24 - Project Proposal:

The Educational Entanglement Device

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1. Introduction

1.1 Objective

We will create an ‘entanglement simulator’ for public demonstrations and outreach. We are working with Professor Kwiat to create a device that should be able to demonstrate Quantum Entanglement in a fun, educational way that can be displayed in the ECEB or the Physics building. Our project should also be able to be easily made and scalable so that other educational institutions can recreate our design to be displayed in whichever areas at whatever scale they need.

1.2 Background

There is currently no demonstration on how Quantum Entanglement works, in an easy and fun way. We have been tasked with creating a display that can help students unfamiliar with the field of Quantum Physics to better understand the properties of Quantum Mechanics.

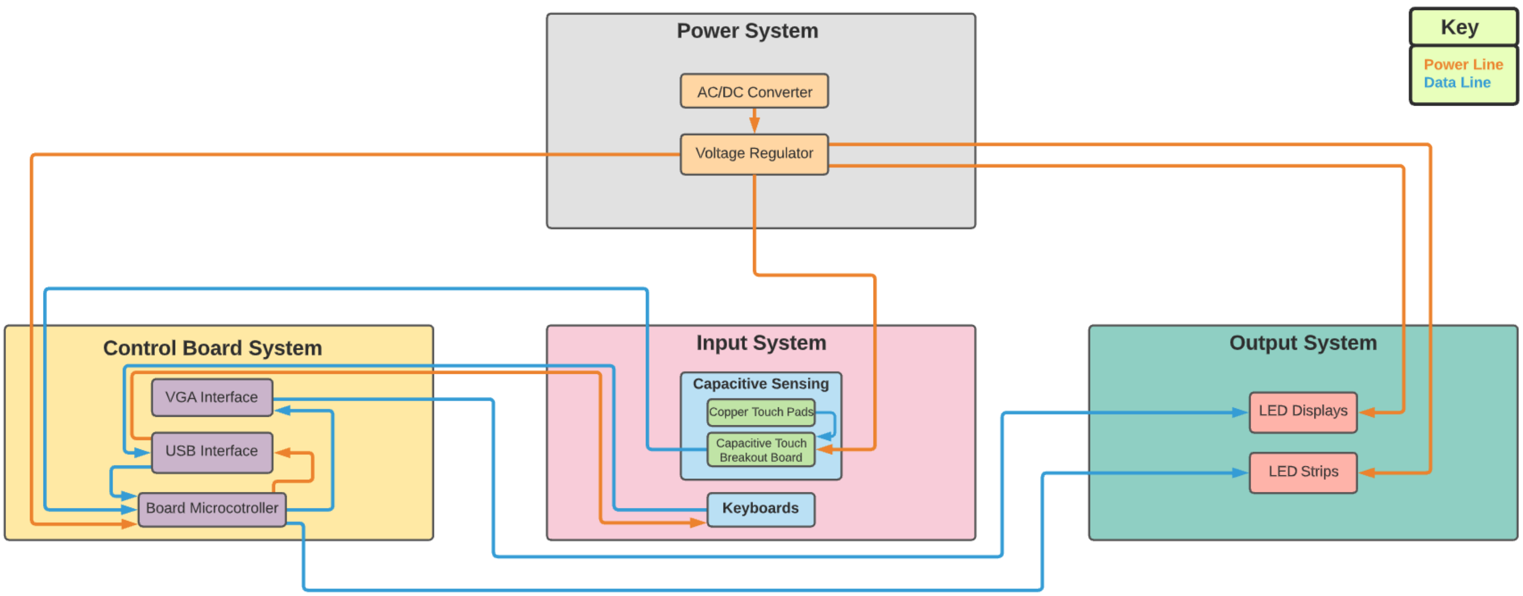
The Educational Entanglement Device: It would feature a central ’source’, out of which come two LED strings, in opposite directions. Correlated light pulses would travel down each string (visible to the observers). The participants could then ‘measure’ the pulses in one of a couple different ways (by touching the strands in a particular way, since we'd like the participants to be able to touch anywhere along a ~3' stretch of the string, but with ~2" resolution of where they touched]), yielding one of a couple results (in accordance with quantum mechanics). These would then be shown on a local display to each of the participants. In addition to demonstrating the basic correlations of entanglement, such a system can also implement a basic quantum cryptography protocol. If the two participants make the same type of measurement, they get the same (but random) result. These can then be used to generate a shared random key, which the project could then use to allow them to send a short encrypted message ("one-time pad").

1.3 High-level requirements list:

- **Touch Precision within tolerance of ~1-2”:** We are going to be using touch sensors, so we want to make sure that when you touch somewhere on the sensor, that it is accurate. So we want to have a maximum tolerance of 1-2 inches to make sure that our device is showing accurate statements.
- **Latency < 200ms:** The user should be able to instantly notice a change after touching the sensor with no noticeable delay.
- **Work for at least 60 minutes with continuous running:** We want this to be displayed in a public place, so we want to make sure that our display can run for at least an hour at a time. It will be plugged into the wall, so the power should be able to make our project run continuously.

2. Design

2.1 Block Diagram:



The design presented in the block diagram contains a power system, control board system, input system and output system. The power system will convert AC power from the wall to DC power for the various modules after regulating the voltage. The Control board system takes input from the Input systems which allows users to interact with the entanglement device and quantum cryptography demo. Once measurements have been made the Control board system then outputs the data to the Output system to display the resulting measurement and encrypted message.

2.2 Power System:

The power system is used to deliver appropriate power to the components in the system by converting AC power to DC and then stepping down voltages as required by the individual components.

2.2.1 AC/DC Converter:

Overview - The AC/DC converter will be used by our project to convert all AC power that we are getting from the wall plug and converting it into DC power that can be used to power our microcontroller, touch sensors, and LED display.

Requirements - The AC/DC converter must be able to maintain at least 70% of the power supplied from the grid and deliver it to the voltage regulation system.

2.2.2 Voltage Regulator:

Overview - Our voltage regulator must be able to properly maintain a safe range of power to each component that requires it so that each component is properly and efficiently powered.

Requirements - The voltage regulator must be able to maintain voltage $\pm$ 0.2V within the designated specifications for each component.

2.3 Control Board System:

The control board system will be a printed circuit board which will be designed to accommodate both VGA and USB communication, and will act as the interface between the input system and the output system in order to achieve the desired behavior of the overall project.

2.3.1 VGA Interface:

Overview - The VGA interface is directed by the board microcontroller, and controls the images being displayed on the LED displays through standard VGA communication protocol.

Requirements - The VGA interface must be able to successfully display images on the LED displays, as directed by the board microcontroller with a refresh rate of at least 30Hz.

2.3.2 USB Interface:

Overview - The USB interface provides a means of receiving user input data from keyboards, and delivering that data to the board microcontroller whereupon it can be utilized as cryptographic messages.

Requirements - The USB interface must be able to accurately deliver keystroke data to the microcontroller without dropping any data or delivering erratic data due to multiple keys pressed in very close succession.

2.3.3 Board Microcontroller

Overview - The board microcontroller is the central processing element of this project. It receives and interprets data from all of the input systems and sensors included in the project, and sends control signals to all of the output systems based on this data.

Requirements - The board microcontroller must be able to perform data operations at a clock speed of at least 10MHz.

2.4 Input System:

The input system consists of a capacitive sensing module and two keyboards which both deliver data to the control board system. The capacitive sensing module uses a capacitive touch breakout board which is able to detect when several different externally connected copper pads are touched, and relays this information to the board microcontroller. The keyboards simply provide standard text input to the control board system for use in cryptographic messages.

2.4.1 Capacitive Touch Sensing:

Overview - The touch sensor allows users to interact with the LED strips to simulate a measurement on the 'entangled particle'.

Requirements - The copper touch pads, along with the capacitive sense breakout boards should be able to deliver touch flag data to the microcontroller with at least 95% accuracy, and the keyboards must be able to communicate with the microcontroller through the usb interface with 100% accuracy.

2.4.2 Keyboard:

Overview - The keyboard will be used to simulate cryptography by having a user interface that allows for the selection of a single key to be converted into a 32 bit number

Requirements - The keyboard should have a latency of <200ms and should be able to send a signal 99% of the time when a key is pressed.

2.5 Output System:

The Output System consists of our LED display and LED strips. This is the most important system in terms of showing off the functionality of our project, as the display and light strips are what simulate the 'entangled particle'. Our display will be used to show different numbers for the entanglement demo as well as letters when demonstrating the encrypted cryptography message. The light strips will be used to simulate the 'entangled particle' being split and sending the two parts in different directions.

2.5.1 LED Displays:

Overview - The LED display is connected to the microcontroller and will output the user's measurement of the 'entangled particle' to the screen.

Requirements - The resolution of the LED display must be able to display a letter with such a clarity that each letter and number can be easily distinguished from one another from 10 feet away.

2.5.2 LED Strips:

Overview - The LED strips are used to simulate the ‘entangled particle’ being split going down two seperate directions.

Requirements - The strips need to have at least a density of 35 LEDs per foot and must have a minimum of 30 Lumens/Watt.

2.6 Risk Analysis:

The biggest issue our project faces will fall under being able to scale up a larger version of our project using the same PCB based on our control board system. As part of our sponsorship, we have been asked to create a working prototype on a much smaller scale. Upon successful completion of this prototype, we will be granted funds that can be used to create a much larger scale version of the prototype, with better LEDs, better monitors, and its own keyboards. The issue with this is that we have to create a working PCB a lot earlier than we were expecting, as well as making this PCB able to handle both the smaller and larger version of the project we will be building. None of our high level requirements will be an issue if we can’t properly scale our project up to the point where it can be displayed in public for demonstrations.

3. Ethics and Safety

3.1 Ethics:

Since we are creating an educational device to be used in a public building for anyone to use, we want to make sure that our device can be operated correctly so that everyone who uses our device will learn about Quantum Entanglement in a fun, safe way. It is important that we follow the IEEE code of ethics throughout our project as we make sure that we hold paramount the safety, health, and welfare of the public by inspecting our device carefully frequently to make sure it is well maintained. This project will be open to all individuals who have a curious mind and wish to see a simple display which shows a much more complex element. We will make sure that the IEEE code of ethics is upheld before, during, and after the construction of this device so that there is no one that will feel unsafe or uncomfortable using it.

3.2 Safety:

With our project being open to the public, we need to make sure that we have the proper safety warnings so that there are no instances of public endangerment. We will be using proper insulation and grounding everything using electricity so that there is no danger of anyone being on the end of any electric shocks. In addition, there can be some sharp edges used, so we will be covering any sharp edges with plastic so that they cannot harm anyone. Due to the ongoing pandemic, we also plan on having a cleaning station available to all those who wish to disinfect the display after each use to stop the spread of germs.

4. References

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