# Project Proposal: Photoresistor Music Board

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# 1 Introduction

## 1.1 Objective

The invention of unique musical instruments and techniques for playing them creates new opportunities for musical expression. In particular, the realm of electronic music still has a lot of unexplored potential for nontraditional music controllers. There is a niche for a music controller that uses electronic sensors and modern DSP algorithms to provide a new level of customization and control over the produced sound.

The instrument that fills this niche is a modular music board that can support multiple types of sensors, such as photoresistors, flex sensors, touch sensors, and more. The sensors and supporting circuitry will be soldered onto modular circuit boards, and an arbitrary number of boards may be joined together. The version we will implement, based on Dr. Eli Fieldsteel's 2017 design, uses photoresistors distributed over an 18 inch by 18 inch region.

The music board will interface with a personal computer running a SuperCollider program, "a platform for audio synthesis and algorithmic composition, used by musicians, artists, and researchers working with sound." [1] The program will process the data sent from the music board and play audio according to which photoresistors are in shadow.

## 1.2 Background

Dr. Eli Fieldsteel, Director of the University of Illinois Experimental Music Studios [2], designed and built a prototype music board that uses photoresistors to detect drops in light intensity. His goal is to design a new and innovative way to generate musical patterns. In the original design, each photoresistor mapped to a sound, and the computer generates music based on the change in intensity at each photocell. With this mapping, a musician can use the music board to play music by casting shadows on the photoresistors.

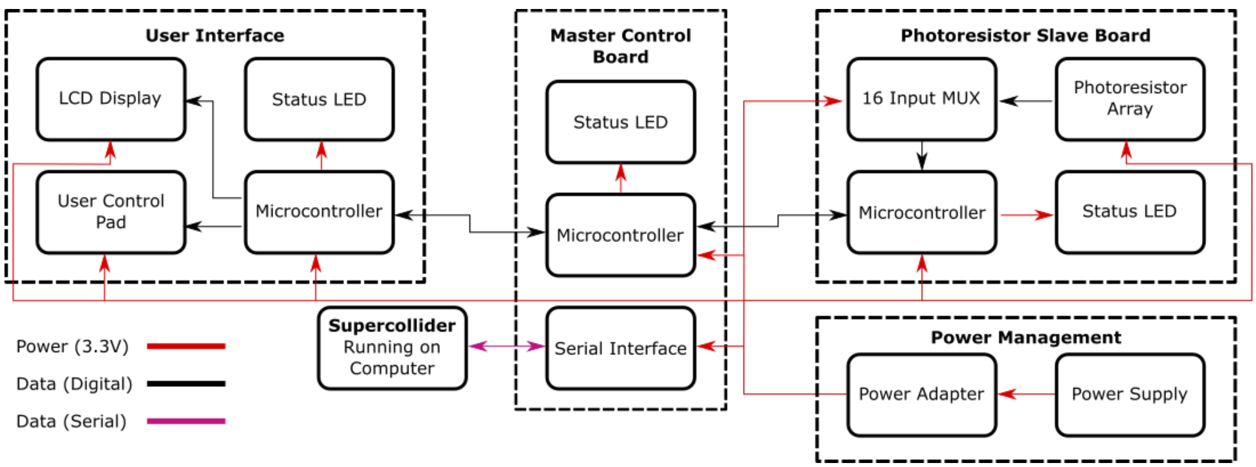
For our project, we will extend Fieldsteel's original work to create a more robust and modular version of his design. His current prototype uses multiple solderless breadboards and insulated wire to connect the photoresistors to the multiplexers. The prototype exhibits structural issues during transport and is overly difficult and time-consuming to debug. The prototype sequentially polls all of the photoresistors, which may limit the board's responsiveness when hundreds of sensors are used. Our design addresses these issues by implementing a modular design, a user interface with debugging tools, and use of PCBs to create a structurally robust design.

## 1.3 High Level Requirements

- The music board must sense changes in light intensity at a frequency greater than 1000 Hz and transmit that data through a serial connection to a laptop computer.
- The music board must have a modular photocell array - so in the event of a board failure, a single board can be easily replaced.
- Design must be robust, capable of handling the stress of travel to national conventions featuring a straightforward setup for performances and onboard diagnostic tools.

# 2 Design

## 2.1 Block Diagram




## 2.2 Physical Design

The entire music board will have the shape of a rectangular prism. The length and width will be around 18 by 20 inches. The height of the music board will be around 0.75 inches. The baseplate will be made of plastic with raised bolt holders to mount the circuit boards to the baseplate. A pane of clear plastic will be mounted above the circuit boards to protect the circuit boards from damage.

The design will include 16 photoresistor slave boards, each with 16 photoresistors spaced on a 4 inch by 4 inch grid with 1 inch separation. Each board will have a total size of 4.5 inches by 4.5 inches with connectors on each of the four sides to allow it to connect to other boards. Each slave board will also feature for screw holes inset a quarter of an inch from each corner so that they can be screwed into the casing.

This design will also include a single master board situated on the edge of the baseplate that connects to a single slave board and connects to the user interface board. This board will be approximately 4 inches by 1 inch. This board will have a connector on one 4 inch long side to connect to a single slave board, and a user interface board connector on a 1 inch long side to connect the user interface.

Finally, the system will include a user interface board that will be at least 4 inches by 1 inch including a small display board and a joystick for control. This board will connect directly to the master control board on the 1 inch side. The joystick for the board will be exposed such that it can be operated while the top layer is covering the photoresistor breakout boards.

## 2.3 Functional Overview and Block Requirements

## 2.3.1 User Interface

### 2.3.1.1 LED display board

The LED display board displays information about the selected preset and debug information (the status of the photoresistor slave boards).

*Requirements:*

- Display system diagnostic information and report errors should any occur.

### 2.3.1.2 User control pad

The pad has buttons for selecting various presets and generating user input signals.

*Requirements:*

- Provide easy control of user menus.
- Enable users to select desired preset within 5 seconds.

### 2.3.1.3 UI microcontroller

The UI microcontroller controls the LED display board based on user input from the User Control Pad. It generates and sends interrupts to master control board if user interface is used to select a new preset. It also outputs error messages and diagnostic information onto the LED display board.

*Requirements:*

- Appear to have immediate response to user requests and send data to supercollider (main computer) within 500 milliseconds.
- Interface with the master control board to communicate any user interface selections and receive system diagnostic information.

### 2.3.1.4 UI Status LED

These status LEDs display when a connection is established between this board and the master control board. The LEDs remain off during board operation to prevent interference.

*Requirements:*

- Respond within 100 milliseconds to indicate errors on board
- Turn off when board is in use.

## 2.3.2 Master Control Board

### 2.3.2.1 Preprocessing microcontroller

This microcontroller pre-processes and packages data for serial transmission to a computer. It generates interrupts to send to slave boards and reads data back from slave board. It also reads data from the user interface board on interrupt and transmits failure codes to the user interface on interrupt.

*Requirements:*

- Respond within 10 milliseconds of serial interrupts from supercollider.
- Generate and control recursive reading algorithm such that a single read cycle takes less than 20 milliseconds of processing time.
- Transmit error messages to user interface within 10 milliseconds of error occuring.

### 2.3.2.2 Serial I/O

Data from the photoresistors and user control pad is relayed by the master microcontroller to a personal computer via USB.

*Requirements:*

- Communicate through USB serial to load new programs to the microcontroller
- Transmit photoresistor data and user interface data.

### 2.3.2.3 Master Board Status LEDs

These status LEDs indicate when the master board is attempting to establish a connection to slave boards. The LEDs turn off during board operation. When diagnostics are run, the LEDs indicate that the board is functioning properly. They also indicate if there is a communication failure between the master board, any of the slave boards, and the user interface board.

*Requirements:*

- Generate interrupts for breakout boards and receive data through digital pins.
- Respond to serial interrupts within 10 milliseconds.
- Send data from user interface and all slave boards to computer system.

## 2.3 Photoresistor Slave Boards

### 2.3.3.1 Photoresistor array

The photoresistor array detects the light intensity of incident light. Each array will contain 16 photoresistors arranged in a 4 by 4 grid with 1-inch spacing between each photoresistor.

*Requirements:*

- Measure light intensity using 16 photoresistors.
- Draw at most 2 mW of power per photoresistor connected.

#### 2.3.3.2 Board microcontroller

The microcontroller controls the multiplexer to read the brightness value of each photoresistor and stores the photoresistor data. It sends interrupts to a board's slave boards, and reads the data from a board's slave boards and store it with this board's data. The board microcontroller receives interrupts from a board's master board, and sends data this board's data and this board's slave data to its the master board. Lastly, it sends control signal to status LED.

*Requirements:*

- Connect 16 voltage divider circuits to a 16 input multiplexer and process the data into an integer array.
- Respond to interrupt signals from supervisor board within 10 ms as packaged data including data from slave boards.
- Send interrupt signal to slave boards and receive photocell data from slave board.

#### 2.3.3.3 Multiplexer

Based on control bits from board's microcontroller, read the analog values from a photoresistor in the photoresistor array and digitally send the data to the board's microcontroller.

*Requirements:*

- Multiplexer must be connected to all 16 photoresistors on each slave board to allow microcontrollers to read photoresistor light intensity.

#### 2.3.3.4 Board Status LEDs

These LEDs indicate that a working connection is established between this board and the master control board. When diagnostics are run, the LEDs indicate that the board is functioning properly.

*Requirements:*

- Provide visual confirmation of connection to master control board.
- Indicate presence of connection error within 10 milliseconds of the error occuring.
- LEDs must remain off during normal board operation.

### 2.3.4 Power supply

#### 2.3.4.1 Power converter

The music board will be powered using a commercially available power supply that plugs into a standard wall outlet. It will convert 120V AC to 9-12V DC and provide between 5 W and 15 W of power [3].

*Requirements:*

- Accept input voltages between 100 V AC and 240 V AC
- Output voltages between 9 V DC and 12 V DC
- Outputs between 5W and 15W of power

#### 2.3.4.2 Power adapter

The power adapter will receive connect the power converter to the PCBs at the master board. This power will be carried through the inter board connectors to all 18 PCBs.

*Requirements:*

- Connect the power converter to the PCB board.

## 2.4 Risk analysis

The largest barrier to successful completion of our project is successfully integrating the 17 separate printed circuit boards. The master microcontroller must connect to all 16 breakout boards to read the value of any photoresistor.

To mitigate this risk, we will create and test prototypes using up to 18 Arduino development boards. The Arduinos will be connected such that one Arduino (the master microcontroller) can perform two-way communication with every other Arduino. After determining the correct method for connecting the Arduinos, we will design and lay out the circuit boards appropriately.

# 3 Ethics and Safety

We are dedicated to upholding and following the IEEE Code of Ethics [4].

An important ethical issue in the field of music is plagiarism, which falls under number seven in the Code of Ethics ("credit properly the contributions of others" [3]). Anyone can perform plagiarism when composing a piece of music and play the plagiarized music on the music board. We will not include a method to detect and disallow plagiarism within the music board. Firstly, the board is intended to be as unrestrictive to the user as possible - signals from its sensors can be processed in any manner using Supercollider programs. Analyzing a piece of music for plagiarized sections is difficult, time-consuming, and often a matter of interpretation and intent; it is not feasible to include such a solution within a musical instrument.

Number one in the Code of Ethics also states to "hold paramount the safety, health, and welfare of the public" [4]. The project is associated with the following safety concerns.

Creating a tabletop instrument that individuals can place their hands over to cover surface mount photoresistors creates risk of injury. To limit contact with the circuit, we will include a clear piece of plastic over the top of the music board to prevent objects and people from directly touching the electronic components. This solution reduces the chances of an individual receiving an electric shock or a cut.

Also, the music board uses a wall adapter to receive power. The power supply must follow strict safety standards to protect people and equipment from AC voltage. To protect people and devices from electric shocks, we will use commercial AC to DC power converters that follow UL standards [5] and are RoHS compliant. Besides the power supply, we will also design and build the power adapter section to safely supply the music board with power. We will also monitor the power draw of the music board and limit it to under 10 W of power.

We will work with Dr. Fieldsteel to not only design a functional instrument, but also to create a safe design that anyone can interact with.

References


[1] SuperCollider. (n.d.). SuperCollider Github Page. Retrieved February 6, 2018, from https://supercollider.github.io/

[2] University of Illinois School of Music. (n.d.). Eli Fieldsteel - Music at Illinois. Retrieved February 07, 2018, from https://music.illinois.edu/faculty/eli-fieldsteel

[3] Arduino. (n.d.). Arduino - Board Reference. Retrieved February 06, 2018, from https://www.arduino.cc/en/Reference/Board

[4] IEEE. (n.d.). IEEE Code of Ethics. Retrieved February 06, 2018, from https://www.ieee.org/about/corporate/governance/p7-8.html

[5] UL. (n.d.). UL Standards. Retrieved February 07, 2018, from https://ulstandards.ul.com/