ASSISTIVE DIGITAL PIANO

ECE 445: SENIOR DESIGN
PROJECT PROPOSAL

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1 Introduction

The average cost of piano lessons in the U.S. is between $15 and $40 for 30 minutes of instruction. If a student takes 1 lesson per week, that adds up to approximately $720 to $2160 per year. In addition, it's been found that many beginning students lose their motivation to play in part because they don't like their piano teacher [1]. Thus, we want to design a assistive digital piano for beginners to make learning to play the piano fun and easy, thereby minimizing the requirement for professional instruction. To do this, our assistive piano will implement many novel features: it will use LEDs and colored gloves to highlight correct fingering; after a song has been played, it will report the timing of the notes and the speed at which the keys were hit so that users can identify what they need to improve; and it will provide a strict "Learning Mode" where the keyboard will wait for the correct finger to press the correct key before it plays the note.

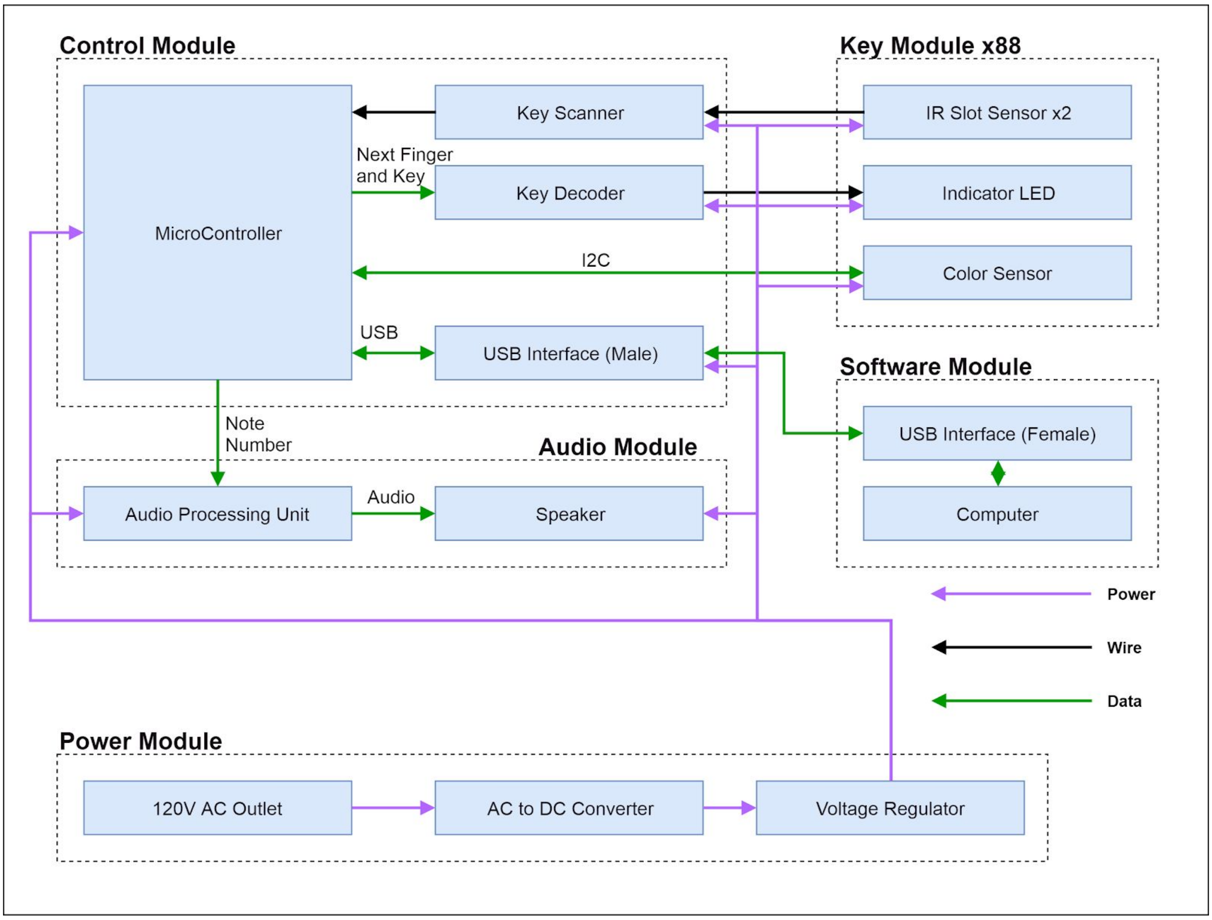
1.3 High-Level Requirements

- The keys must be able to identify which finger is used to press which key within 5 ms with 95% accuracy.
- The piano must be able to decode song files that we design, and not allow incorrect key/finger inputs to play sounds while in "Learning Mode".
- The project's user interface must be able to read rhythm and keypress data from the piano and then evaluate and display rhythmic accuracy and keypress accuracy to the user.

2 Design

Block Diagram

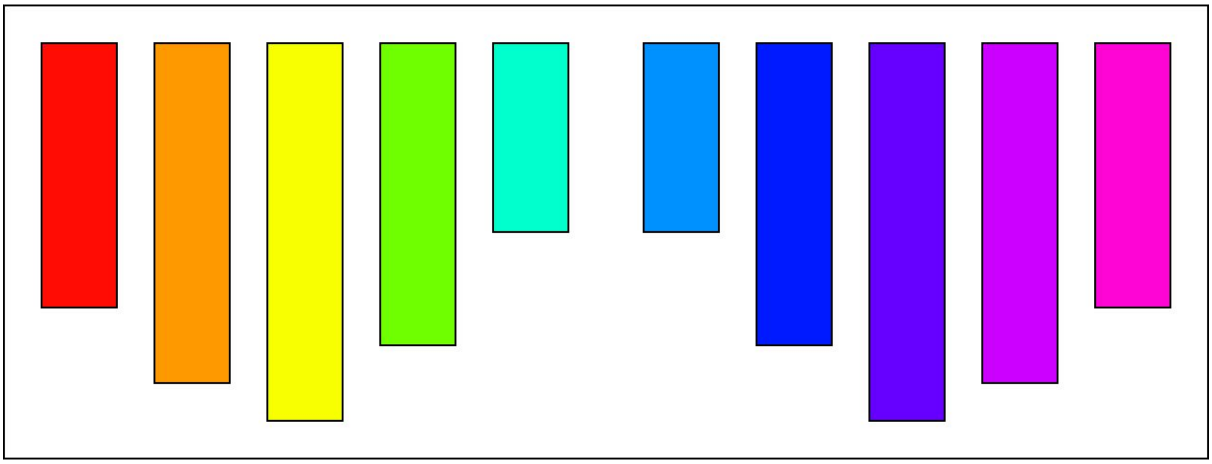
Figure 1: Block Diagram



Physical Design - Glove

The user will wear thin gloves with colored fingertips

Figure 2: Finger Colors



Colors (subject to change):

Left Pinky: #FF0000
Left Ring Finger: #FF9900
Left Middle Finger: #F7FF00
Left Index Finger: #6FFF00
Left Thumb: #00FFCC

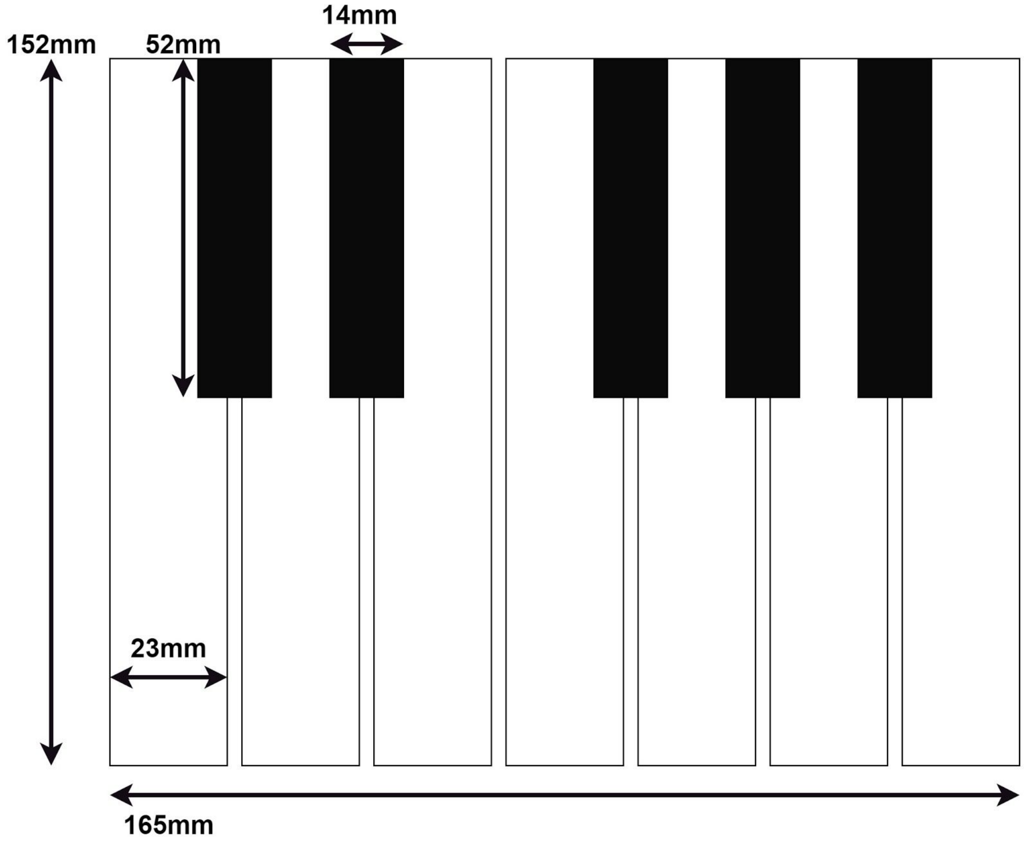
Right Thumb: #0091FF
Right Index Finger: #001AFF
Right Middle Finger: #6600FF
Right Ring Finger: #CC00FF
Right Pinky: #FF05D5

Physical Design - Keys

Our piano will attempt to model the dimensions of a real upright or grand piano as closely as possible. All measurements and locations at this stage of the design are approximated. Piano key measurements were taken from a real piano and online resources.

White key depth: 25mm, depression distance: 20mm
Black key depth: 10mm, depression distance: 8mm

Figure 3: Approximate Key Dimensions (not to scale)



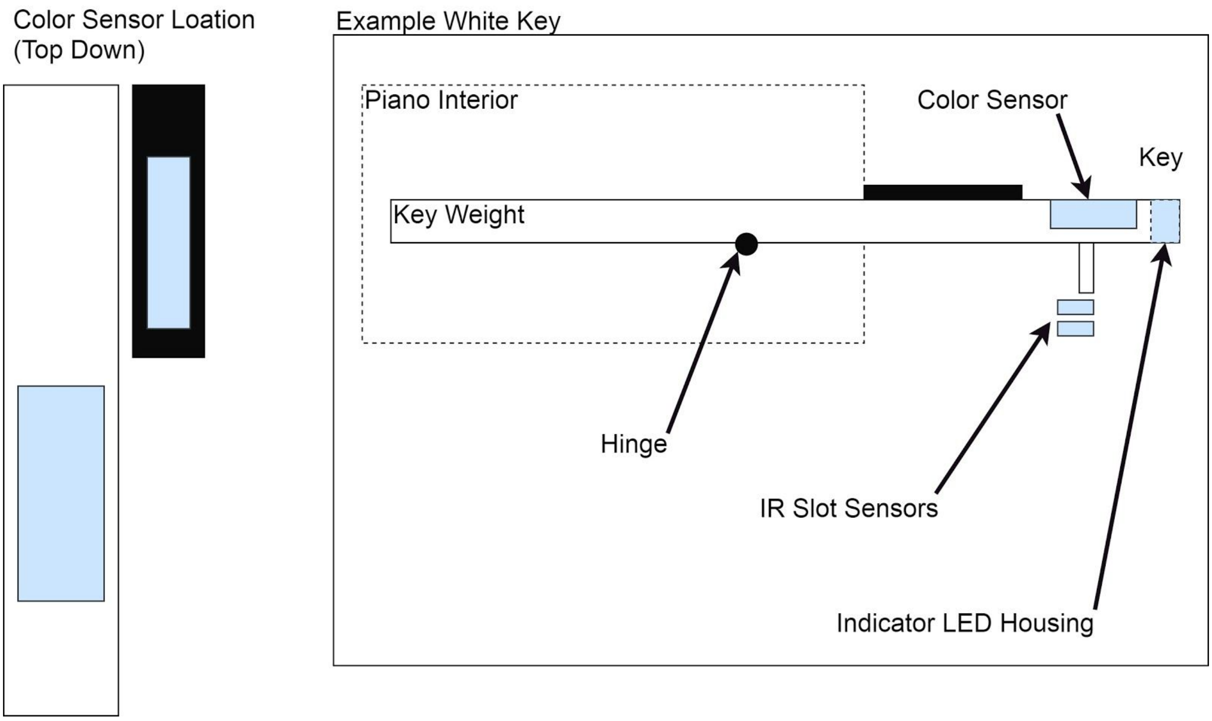
Physical Design - Keys (Continued)

IR slot sensors will be placed beneath the keys, and will be triggered by a thin protrusion on the bottom of the key that will trigger them sequentially when the key is pressed.

Our microcontroller will be scanning all 88x2 inputs from the IR sensors as digital signals with the help of the key scanner sub-module. When the key is slightly depressed, the first IR slot sensor will be triggered, and our microcontroller will record the time at which it was pressed. Then, when the key is almost fully depressed, the second IR slot sensor will be triggered, and the microcontroller will calculate the time difference between the two triggers and send a note signal to the audio controller with a volume that is inversely proportional to the time difference. Therefore, the faster the key is pressed, the louder the note will be played.

If the piano is in “strict” mode, our microcontroller will simultaneously be reading in RGB values from the color sensors and converting them to finger values. As the diagram below shows, the color sensor is located facing upwards to read in the RGB value of the finger being used to press the key. If the fingering or note number of the input is wrong while in this mode, the microcontroller will not allow the note to be sent to the audio controller.

Figure 4: Approximate Sensor Layout (not to scale)



Circuit schematics

Our design for the circuitry of our piano first involves turning the 6 bits of data we receive from our sensors into a 1 bit signal polled by the microcontroller. This is done by our efficient data transfer module (Figure 6). The 1 bit signals from that module are fed through a series of transistors controlled by an output pin on the microcontroller. There are 8 identical efficient data transfer modules and 8 output signals from the microcontroller corresponding to 8 different octaves (note, the last “octave” contains only 4 keys). When the microcontroller sends a signal to the transistors for a particular octave, the 1 bit signals from that octave’s efficient data transfer module are connect to a bus that sends

Figure 5: Interface Between Sensors and Microcontroller

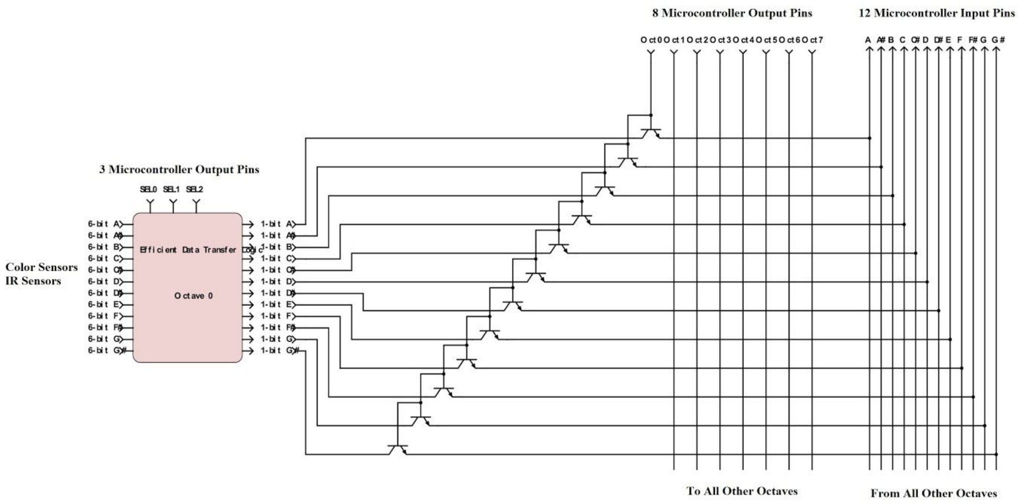
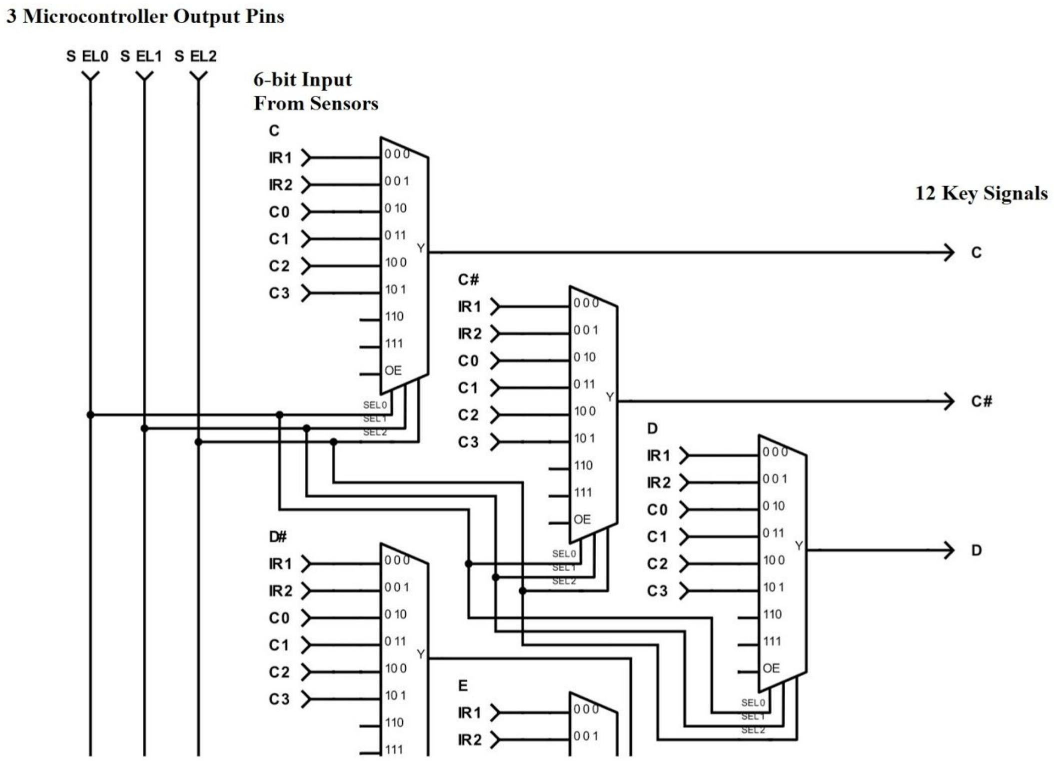


Figure 6: Efficient Data Transfer Module



Functional Overview

Important Calculations and Estimates:

The fastest possible piano key press will be assumed to hit the IR slot sensors with less than 1 millisecond of delay from the first to the second. In the case that both sensors are triggered in the same round of a key scan, our microcontroller should still interpret this is a legitimate key press and play the note at maximum volume. A slow keypress will likely be around 20-100 milliseconds of delay. Our key scanning should be fast enough to detect the nuance in these presses, and therefore scan all the keys at intervals of less than .25 milliseconds. Note that all of these measurements are at best educated guesses in this point of the design. The delays were measured with an arduino push button prototype. The relationship curve between speed and volume will be finalized when a physical design of the key can be tested.

Temporal delay in the input vs sound output is also a consideration. Sound travels at approximately 1 meter per millisecond. Since the literature on human time perception is wide, varied, and very specific to the situation, we will approximate that the maximum acceptable delay from piano input (triggering the second IR sensor) to sound output is 10 milliseconds.

The visible color spectrum is around 400nm to 700nm. Since there are 10 fingers, we need to partition segments of the color spectrum for finger color detection.

Requirements and verification

MODULE	REQUIREMENTS	VERIFICATION
Power	**1)Voltage regulator:** 1.1)The voltage across the output terminal and ground must be 3.3/5V with a maximum error of ±5% when connected to a DC supply of 12V	1.1 a)Connect E3631A Triple Output DC Power Supply to the input of the regulator circuit and tune its output voltage to 12V . b)Connect 34461A 61/2 Digit Multimeter to the output of the circuit and measure the voltage. c)The measured voltage should be between 3.3/5V ±5%
Key Module	**1)IR sensor:** 1.1)Top sensor must be able to detect key press when a white key is pressed 3 mm from its resting position, and when a black key is pressed 1 mm from its resting position with at least 99% accuracy	1.1 a) supply 5 V DC power supply to the input of the Input of the IR sensor 1 nad sensor 2. b)connect a digit multimeter across IR sensor 1 and sensor2. c)The multimeter must show 0V±5% if the key is pressed by 3mm for a white key and 1mm for a black key . It should show 5V±5% if no key is pressed

3 Safety and Ethics

3.1 Safety Issues:

As with anything that connects to a wall outlet, there's a minimal chance of electrocution or fire if the plug/circuitry is tampered with, misused, or accidentally compromised. Should we or someone else choose to market our design, we would ensure that a safety warning is included in the packaging as per the IEEE Code of Ethics #1, "... to disclose promptly factors that might endanger the public or the environment," [2].

Also we need to ensure that the color casing for the color sensors is able to tolerate the force of key presses and does not expose these sensors to come in direct contact with human skin.

3.2 Ethical Issues:

The most likely ethical issue we'll face will be accurately reporting the capabilities of our project. It is difficult for us to tell at this stage how accurate and robust our design will be. Nevertheless, we will maintain the integrity of our work and be honest even if the final product falls below expectations in keeping with the IEEE Code of Ethics #3 [2].

Also of great importance to our project is the IEEE Code of Ethics #7 [2]. We will welcome criticism of our work and do our best to fix any errors in our project. In keeping both with the aforementioned IEEE policy and also with one of the University of Illinois's most important policies, we will not plagiarize anyone else's work and will give credit to outside sources whenever necessary.

Lastly, in keeping with the IEEE Code of Ethics #10, we will offer our aid to any of our fellow peers in their projects should they need it given we have the requisite knowledge and resources to do so [2].

References

[1] A. Mazzocchi, “Why Students Really Quit Their Musical Instrument (and How Parents Can Prevent It),” *The Music Parents' Guide*, 17-Feb-2015. [Online]. Available: http://www.musicparentsguide.com/2015/02/17/students-really-quit-musical-instrument-parents-can-preven. [Accessed: 08-Feb-2018].

[2] “IEEE Code of Ethics,” *IEEE*. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 08-Feb-2018].

[3] “How Colour Changing LEDs Work,” *Kitronik*. [Online]. Available: http://www.kitronik.co.uk/blog/how-colour-changing-leds-work. [Accessed: 08-Feb-2018].

[4] “Tempo,” *Wikipedia*. [Online]. Available: en.wikipedia.org/wiki/Tempo#Basic_tempo_markings. [Accessed: 08-Feb-2018].

[5] “Musical Keyboard,” *Wikipedia.* [Online]. Available: en.wikipedia.org/wiki/Musical_keyboard. [Accessed: 08-Feb-2018].