Musical Hand Proposal

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Introduction

Problem

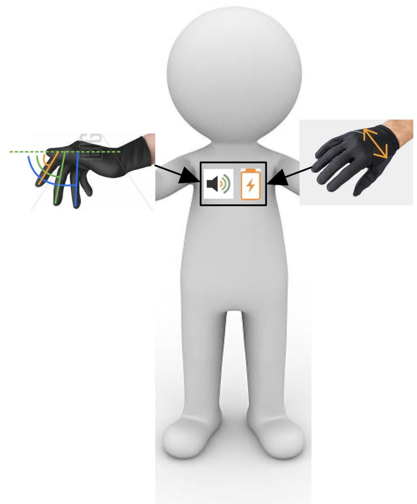
Musical instruments come in all shapes and sizes; however, transporting instruments often involves bulky and heavy cases. Not only can transporting instruments be a hassle, but the initial purchase and maintenance of an instrument can be very expensive. Any musician with sufficient experience in playing stringed instruments can attest to the issues of durability, even mid-performance, caused by physical synthesis. The cost of simply purchasing an instrument can range from the low hundreds to over a thousand dollars. We would like to solve this problem by creating an instrument using electronic synthesis that is lightweight, compact, durable, and low maintenance.

Solution

Our project involves a wearable system on the chest and both hands. The left hand will be used to dictate the pitches of three “strings” using relative angles between the palm and fingers. For example, from a flat horizontal hand a small dip in one finger is associated with a low frequency. A greater dip corresponds to a higher frequency pitch. The right hand will modulate the generated sound by adding effects such as vibrato through lateral motion. Finally, the brains of the project will be the central unit, a wearable, chest-mounted subsystem responsible for the audio synthesis and output.

Our solution would provide an instrument that is lightweight and easy to transport. We will be utilizing accelerometers instead of flex sensors to limit wear and tear, which would solve the issue of expensive maintenance typical of more physical synthesis methods.

Visual Aid



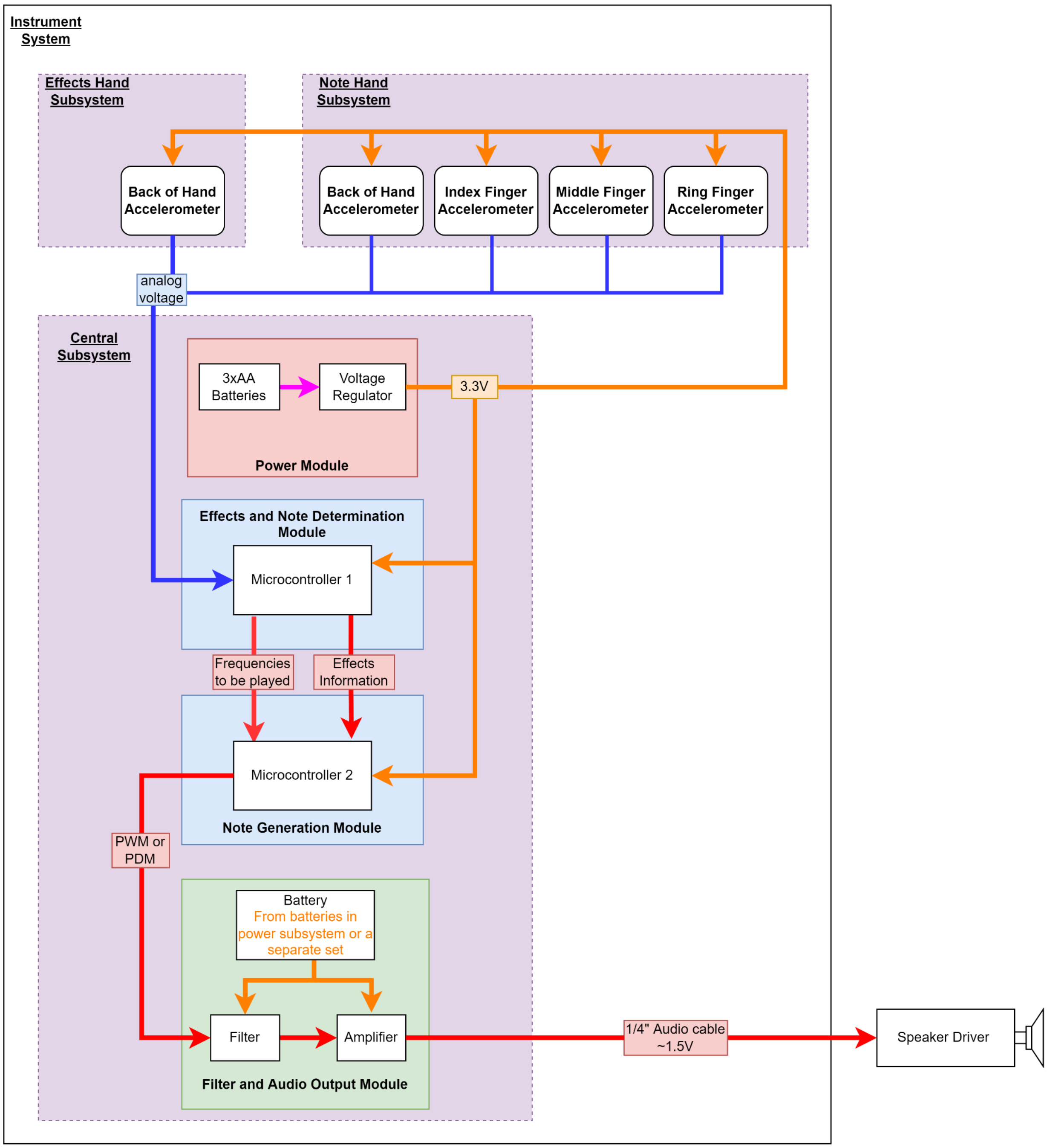
High-level requirements list

The requirement for a minimally viable product are as follows:

- All components (sensors, microcontrollers, speaker driver) can successfully communicate over worn physical connections to generate a human audible output.
- The right hand is able to apply a vibrato sound effect, slightly modulating the perceived pitch.
- The output frequencies should range from 196 Hz (G3) to 1760 Hz (A6); each finger will approximately cover two octaves.

Design

Block Diagram



Subsystem Overview

Subsystem 1 - Note Hand (Left Hand)

The left hand subsystem will use four accelerometers total: three on the fingers and one on the back of the hand. These sensors will be used to determine the angle between the back of the hand and each of the three fingers (ring, middle, and index) being used for synthesis. Each angle will correspond to a pitch/note. For example, a completely straight finger corresponds to a lower pitch and a completely bent finger corresponds to a higher pitch. This subsystem passes data to the central subsysteem and also receives power from the power module in the central subsystem.

Subsystem 2 - Effects Hand (Right Hand)

The right hand subsystem will use one accelerometer to determine the wrist rotation (roll) of the hand. This information will be used to determine how much of a vibrato there is in the output sound. The effects hand subsystem passes sensor values as data to the central subsystem and receives power from the power module in the central subsystem

Subsystem 3 - Central Unit

The central subsystem processes data from the accelerometers to determine and generate the correct audio. Both the note hand and effects hand are connected to the central subsystem through cabling and will deliver data from the accelerometers. The central subsystem houses two microcontrollers and will use the accelerometer data to calculate the frequencies of each pitch to be played and how modulation will be applied to the output audio. The central subsystem also contains the power module, which will be used to provide power to the rest of the subsystems.

Subsystem Requirements

Subsystem 1 - Note Hand

The note hand will consist of four 3-axis accelerometers; we plan on using Analog Devices' ADXL335BCPZ-RL7. The measured accelerometer values will be passed as analog signals to the on-board ADCs of Microcontroller 1 in the central subsystem. These sensor values will be used to calculate the angle each finger forms in relation to the back of the hand. Each finger will cover a different range of frequencies (approximately two octaves) and each angle will correspond to a pitch within that finger's range. To filter out AC noise, bypass capacitors and possibly resistors will be used when sending the accelerometer signals to Microcontroller 1 in the central subsystem.

Requirements:

- Accelerometers must output a voltage between 0-3.3V that varies with finger and hand motion

Subsystem 2 - Effects Hand

The effects hand contains a single accelerometer across the back of the right hand. We are planning to use the same accelerometers from the note hand subsystem in the effects hand. The accelerometer will be connected to an on-board ADC of Microcontroller 1 in the central subsystem. The sensor values passed in would be used to determine the rolling movement of the right hand. This motion will be used to calculate how much vibrato to apply to the pitches generated from the note hand's data. To filter out AC noise, bypass capacitors and possibly resistors will be used when sending the accelerometer signals to Microcontroller 1 in the central subsystem.

Requirements:

- Accelerometers must output a voltage between 0-3.3V that varies with the roll (wrist rotation) of the hand

Subsystem 3 - Central Unit

The central subsystem takes input from the effects and note hand subsystem to generate audio output. To do this, two microcontrollers from the Microchip PIC32 series will be used. Microcontroller 1 will receive information from the sensors on both gloves and use it to calculate the correct frequencies. Microcontroller 2 uses these frequencies and wavetable synthesis to generate the actual audio output. The use of two separate microcontrollers allows for the logic to take longer, accounting for slower human response time, while meeting needs for quicker audio updates. At the output, there will be a second order multiple feedback filter. This will get rid of any switching noise while also allowing us to set a gain. This will be done using an LM358 Op amp along with the necessary resistors and capacitors to generate the filter and gain. This output will then go to an audio jack that will go to a speaker. In addition, bypass capacitors, pull up resistors, pull down resistors, and the necessary programming circuits will be implemented on this board. The central subsystem also contains the power module, which consists of 3 AA batteries and a voltage regulator.

Requirements:

- The unit needs to be able to receive analog signals as input and convert them to 12-bit digital data for processing.
- Microcontroller 1 needs to be able to appropriately map inputted accelerometer data to playable frequencies and a frequency modulation factor for vibrato that are sent to Microcontroller 2.
- Microcontroller 2 must create waveforms between 196 Hz (G3) and 1760 Hz (A6) modulated by vibrato that are outputted using either Pulse-Width Modulation or Phase Density Modulation.
- The central system must be able to output an instrument line level (-0.1 - 2V Peak-Peak) audio signal, allowing for use with conventional professional grade audio technology. This needs to be achieved by filtering and amplifying the PWM or PDM signal after it is output from the note generation microcontroller.
- The linear regulator needs to supply 3.3V with .52A of current maximum to power the system. From this datasheet, a single AA battery should be able to last 3hrs at 1A of current, so the batteries will have the capability to drive everything.

Tolerance Analysis

The largest source of error will be the power dissipated by the microcontrollers. This varies significantly based on the temperature and the amount of work that the controller is doing. From the data sheet, if the peripheral clocks are enabled and the CPU is running, then each controller will draw 45mA plus the current for each I/O pin output current. The microchip that is doing the frequency determination will have at most 16 I/O pins being used, and the microchip that is controlling the output will have one pin. Since each I/O pin has a maximum current output of 25mA, we get 515 mA of current to the microcontrollers at worst case usage. This point should never be reached as the 25mA per IO pin would normally only occur at 1.5V logic, but for the sake of safety, we will use this as the upper bounds of input current. Each accelerometer draws .35mA of current typically. Since this value does not change with temperature, this means that if we can supply 520 mA of current, we will be able to successfully drive everything despite temperature variations.

Another source of possible error will be in the accelerometers. On the datasheet, the worst cane change in voltage across the temperature range the device is set for is 20mV. However, all of our accelerometers are isolated from major heat sources. This means that the largest temperature variation that can occur would be from room temperature to body temperature. Since these two temperatures are close, the variation in voltage will be on the order of single mili-volts, so the error will be small enough that the ADCs will ignore the error.

Ethics and Safety

Keeping with the IEEE code of ethics, safety and health of the public must be held paramount. The main ethical and safety concerns of our project involve the audio output and power source. Since the power source is part of the chest mount, we must ensure that it does not overheat and burn the user. This requirement can be effectively tested separately from the chest mount, so no human subjects will be at risk of getting burned during the development process. As for the audio output, we must ensure that our product maintains a reasonable volume and does not generate any frequencies that cause discomfort (ex: very high frequencies). While some frequencies and volumes can become uncomfortable, they do not pose a serious health risk and can be tested without additional users outside of the development team.