VoxBox Robo-Drummer

Team 27: Craig Bost, Nicholas Dulin, Drake Proffitt
ECE445 Project Proposal Spring 2018
TA: Zhen Qin

Introduction

Objective

Our design seeks to enable a human user to convert live “beatboxing” performance into real-time physical performance by a robot. As such, our design is best thought of as musical instrument in its own right: when “played” as intended, our design will respond by instructing a robot drummer to strike the corresponding drum kit component. Correctly “playing” our system amounts to the human user constraining their vocal performance to a subset of sounds which can be identified as comprising traditional “beatboxing” (see Background below for elaboration). This mapping of performative sounds to the correct corresponding robotic performance comprises the core challenge of our design.

Our design is distinct from existing designs which similarly process “beatboxing” into equivalent musical forms, as these existing systems typically only convert recordings of “beatbox” performance into drum samples for music production; as such, these existing systems are purely software-based and non-real-time, whereas our design will feature real-time performance, driven by hardware-software embedded systems.

One possible social application for our system, which is not met by these other existing systems, is the capacity for persons with mobility restrictions of their extremities to be able to participate in live music performance, in a manner consistent with typical rock music performance.

Background

“Beatboxing” refers to the practice of emulating conventional percussion musical instruments with only one’s mouth, and typically incorporates a voice microphone and amplification system. Correct beatboxing would be characterized by a vocal performance that approximates or imitates conventional percussion instrument to a sufficient degree of fidelity that the performance could substitute the drum track in lieu of the actual instruments.

In this respect, our design “completes the circle,” by using the imitative human performance to play the very instrument they are attempting to emulate.

High-Level Requirement

1) Device must be able to receive beatbox audio input from a human user/performer and distinguish between 3 different key sounds. This implies that there are 4 valid inputs in total: clap, snare, bass kick, and no input.
2) Device must be able to perform requirement (1) in real-time (defined in accordance with conventional electronic musical instrument latency standards) and drive a machine based on said inputs.

3) The machine will have 3 drums, one for each input, and will strike the correct drum which corresponds to its input.
4) The drums must generate enough noise so that they can be heard in 20 ft^2.

Design

The overall design is essentially a unidirectional A/D/A chain: as shown in Figure 1 below, a continuous-time acoustic signal is converted into a continuous-time electrical signal (microphone input), which is sampled and analyzed for event triggers (DSP), which are in turn relayed to an electromechanical system as stimulus to the robot drummer (electromechanical), whose performance provides the output acoustic continuous-time signal (mechanical). It is the D/A portion which constitutes the whimsical twist on conventional DSP applications of working in the digital domain to effect a new output in the analog domain: our digital-to-analog converter is a digitally controlled robot exciting an analog signal source (e.g. drum kit), as shown in Figure 2.

<u>Block Diagram</u>

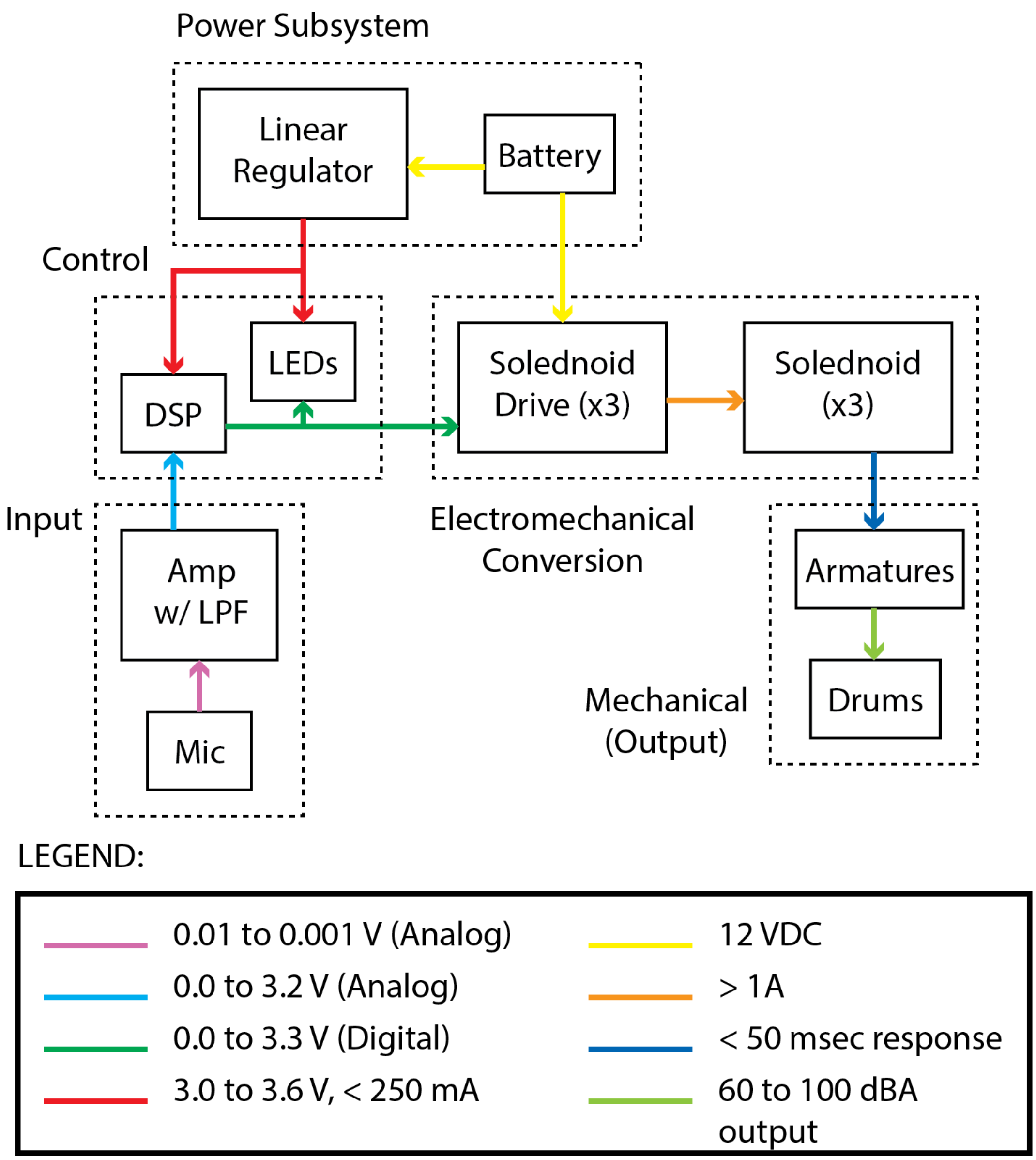

Figure 1

Physical Design

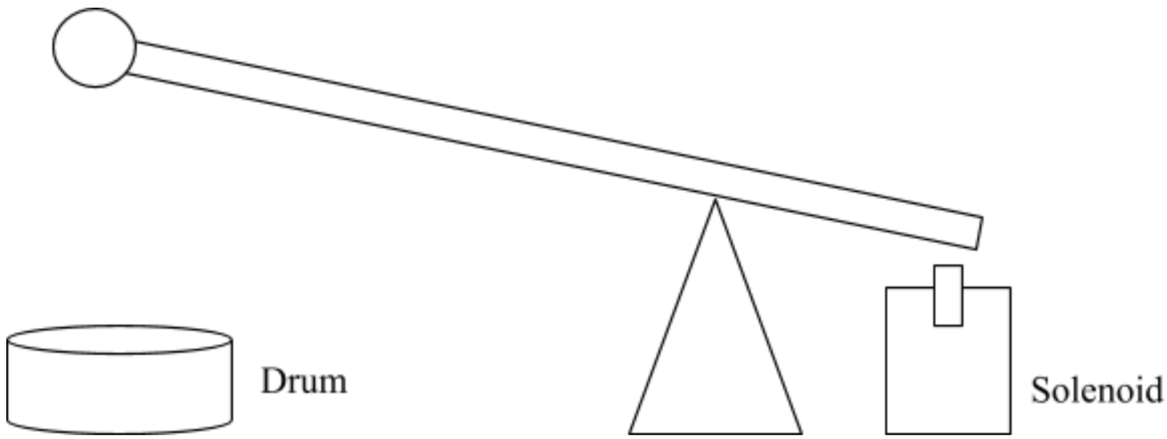

Figure 2

Functional Overview

Power Block:

Battery
The entire system will be powered from a 12V battery.

Linear Regulator
The linear regulator will step down the battery voltage to supply power to the microcontroller and LED's.

Audio Input Block

Microphone:
Audio input is provided a dynamic microphone characterized by mic-level output voltage (generated by the moving-coil of the microphone diaphragm) and a sensitivity range fallings within 20 to 3300 Hz (± 200 Hz).

Amp with LPF:
The microphone output is routed through an amplifier to conform the signal levels to appropriate tolerances for the MCU chip's ADC input pins, and passed through an anti-aliasing low-pass filter to ensure a bandlimited signal profile. Lastly, this conditioned signal is then passed to the DSP chip via its ADC analog input pins.
This portion of the design will use as reference an existing design implemented by Microchip for their Audio Starter Kit, which is used to convert mic level input voltage levels to those within the bounds of their DSP chip's ADC input pins.

Control Block:

DSP:

The DSP-MCU is comprised of microcontroller with DSP support, which performs the sampling of the analog input signal, digital filtering, Fourier Transform analysis, and event detection. It will also fulfill the role of traditional microcontroller by issuing digital control signals in response to its event detection routines, sending digital trigger signals out via its digital I/O pins to the electromechanical conversion subsystem.
The microcontroller will require standard power (3.3 V, < 300 mA), and the analog input signal will need to be constrained to range of 0 to 3.3 V (± 10%) and current < 25 mA. The digital output signals will fall within 0 to 0.5 V for low voltage, and 2.8 to 3.3 V for high voltage, at < 100 mA current.

Electromechanical Conversion Block:

Solenoid Driver

This circuit takes a digital input from the microcontroller which indicates if a drum strike should occur, and then it supplies current to the solenoid. It will be equipped with a capacitor bank so that it can supply large surge current that the solenoid will require.

Solenoid

This device will convert electrical energy to the mechanical energy needed the drive the drummer.

Mechanical/Audio Output Block:

Armatures

The armatures comprise the robot drummer's "limbs," serving as the means by which the electromagnetic force of the solenoid is translated into mechanical energy striking the drums. As such, it will provide the physical scaffolding for the solenoid actuators and elastic retraction mechanisms, as well as a mounting for the drum sticks.
The armatures will need to receive enough force from the solenoids to overcome the elastic resistance of the retraction mechanism, but not so much that drum-strike is excessively hard, to avoid damage to percussion instruments and/or robot itself.

Drums

The drums comprise the final part of the analog output, as the mechanical transducer of mechanical energy back (the drum strike) into acoustic energy (percussion sounds).
For the purposes of this design's scope, as we are using a small scale robot and not a human-sized replica of a drummer, the drums will be similarly sized. As a whimsical touch, the drums in question will be taken from everyday pots and pans.

Block Requirements

Block	*Requirement (Output)*	*Comment*
Microphone	0.01 to 0.001 V, ± 10%	Confirmation of industry-standard mic-level voltage.
Pre-Amp and Filter	0.0 to 3.2 V, ± 10% < 30 mA 3300 Hz cutoff, ± 200 Hz	Teensy chipset requires analog signal input to fall within 0.0 to 3.2 V, with a tolerance of 0.3 V. (Teensy Datasheet, pg. 45)
DSP	2.8 to 3.3 V, ± 10% < 100 mA	Teensy chipset I/O pins provide digital output signals within 2.8 to 3.3 V, with an upper-bound tolerance of 0.3 V. (Teensy Datasheet, pg. 9)
LEDs	3.3 V, ± 10% 20 mA avg, 80 mA peak	Indicator LEDs will be wired active-low to the digital out of the DSP block, so voltage will be provided at 3.3 V and 20 mA to drive the LEDs
Solenoid Drive	Response time < 10ms, Supply > 1A to solenoid	Must have a high impedance input to prevent drawing the rated current from the MCU.
Solenoid	Response time < 50ms, 50mm(2 inch) throw.	This should be a push-pull type solenoid so it can perform the actions of inducing the drum strike, and resetting the drummer arm.
Actuators	1 foot long arm with pivot located 3 in from end.	These are the arms which are driven by the solenoids. They will be mounted on a pivot where the longer lever arm strikes the drum, and the shorter lever arm is driven by the solenoid.
Drums	> 60, < 100 dBA at 3 ft	Drum strike will produce a sound that is at least 60 dBA measured from a distance of 3 ft, but not more than 100 dBA for hearing safety. (http://www.dot.ca.gov/dist2/projects/sixer/loud.pdf)
Battery	12 V	
Linear Regulator	3.3 V, ± 10% < 250 mA	Per Teensy operating requirements, linear regulator will provide with 10% tolerance 3.3 V, no more than 250 mA of current. (Datasheet, pg. 259)

Table 1

Risk Analysis

The DSP subsystem is the ‘heart’ of our design. It handles both dsp and control, and acts as the interface between audio input and mechanical output. Without the DSP subsystem we lose the ability to process audio signals and trigger the appropriate mechanical reactions. It suffices to say that without the DSP subsystem our product would be rendered useless.

The DSP subsystem will contain a microprocessor chip wired for analog input (ADC conversion) and digital output. The processor will be used for real-time FFT calculations, and run sound identification algorithms. The most difficult part of designing the subsystem will likely come from implementing the design on PCB. Though all group member have TTL experience from 385, few of us have experience implementing on a chip as complex as a microprocessor. We also have little experience with PCB implementation. We hope to mitigate programming difficulties by using an intuitive-by-design device.

Ethics and Safety

Ethics

The device will be used for entertainment purposes. As mentioned, it can be considered a musical instrument, and thereby risks violating few, if any, ethical considerations.

Safety

Being that our device is electrically powered, the user will need to be made aware of the electrical hazards it presents. These hazards are present in almost all electrical devices and include things such as fire, electrical shock, and burns. We aim to mitigate these electrical hazards by abiding by electrical device regulations present in the United States.

Additional safety hazards include the sound intensity of the robot drummer’s drum strikes, which must remain below 110 dBA to avoid potential hearing damage. We intend to mitigate these risks by limiting the power output of our robot drummer’s armatures to render drum sound events in excess of 100 dBA impossibly likely.