LightsaberFX
Project Proposal
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Introduction

We all grew up with the magic of play-pretend - a branch becomes a powerful sword, a bear becomes a trusty explorer. With the lack of real weapons and heros, we used our imaginations to fill in the rest of the details and create our own worlds - we can reflect on memories of holding invisible swords, making sounds with our mouths and shining flashlights at each other to replicate intergalactic battles. However, sometimes frustration can arise with keeping track of small but vital details, like making the sound of a lightsaber, while leaving room for generating plot and action scenes.

How can we engage young kids and supplement the growth of their creativity? One way to catch their interest is to develop a toy that is “interesting” - this means it must be interactive, easy to use, and versatile. Children are attracted to and excited by toys that produce sound and that respond to their physical interaction - if they move it around, they get a reaction. How do we deliver such an experience? For our project, we would like to encourage people to foster their imaginations by developing a module that can be attached to any object, whether a toy or an everyday object, and turn it into a lightsaber. This allows for endless possibilities for entertainment and innovation as kids find various ways and places to attach the module and wave it around.

LightsaberFX aims to create an interactive experience by generating lightsaber sound effects according to the user’s awesome bladework. By attaching an accelerometer to a lightsaber, we can acquire movement data in three axes and transform it using operational amplifiers and filters to send to a sound generator. We will assign various speed, acceleration, and duration thresholds to particular sounds created by analog oscillators, filters, and modulators. In order to for the sounds to be appreciated, we will also need to design a power supply and an amplifier. Ultimately, we aim to develop a wireless system that sends motion data through Bluetooth or through RF signals to the sounds system, and also allow for the capability of multiplayer participation by adding effects prompted by two lightsabers hitting each other. If time permits, the option to expand the effect bank with lights and increasingly complex sounds exists. Through this project, we hope to aid the user in realizing their inner lightsaber warrior at present, in a galaxy not too far away.

Block diagram

The main two parts of the project are data acquisition from the accelerometer, which obtains information about speed and acceleration, and sound generation, which creates the special effects by modulating signals. This can be summarized by Figure 1:

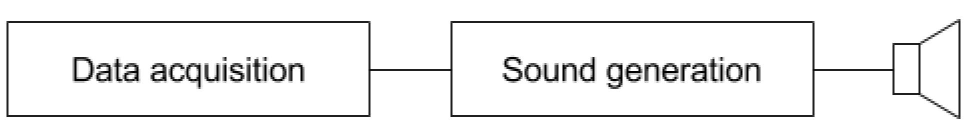

Figure 1. General schematic of the Lightsaber Module

If we break down each of the two parts further, we have the block diagram in Figure 2. Each block will be described in detail in the next section.

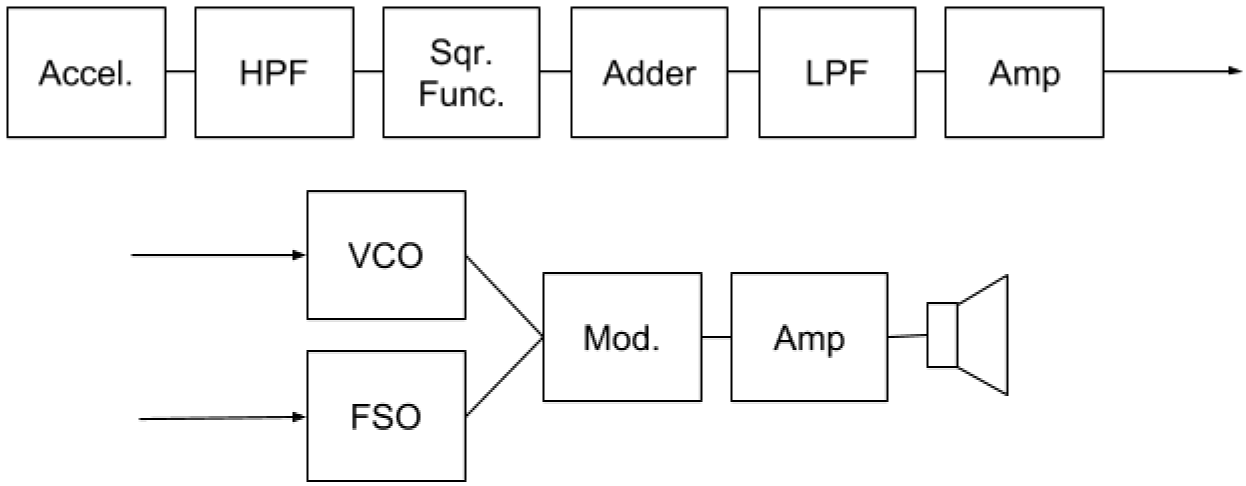

Figure 2: Block diagram

Accelerometer

The accelerometer will be attached to the tip of our lightsaber to maximize the measured torque. The accelerometer runs on 3.3V, which will be supplied by the 9V battery. The output due to movement for each axis will be on the range of 1V peak-to-peak, with some amount of offset dependent on the angle caused by the acceleration due to gravity. The DE-ACCM3D is a tri-axis accelerometer that outputs acceleration data in the x, y, and z axes.

High Pass Filter

In order to remove the DC offset from the acceleration due to gravity to focus on the acceleration only due to movement, the signal will be passed through a high pass filter with an LF353 op amp as the DC offset will resemble a signal with a very low (zero) frequency and be filtered out.

Squaring Function and Adder

Since the DE-ACCM3D accelerometer outputs data from 3 separate axes, to obtain the overall magnitude of the saber's acceleration, the output of each axis will be passed through a squaring circuit. Three squaring circuits will be built in parallel, with one for each axis of movement. After passing through the squaring circuit, the three outputs will be passed through an op amp adder to get the squared magnitude of the total acceleration, whose value will be no more than 3V.

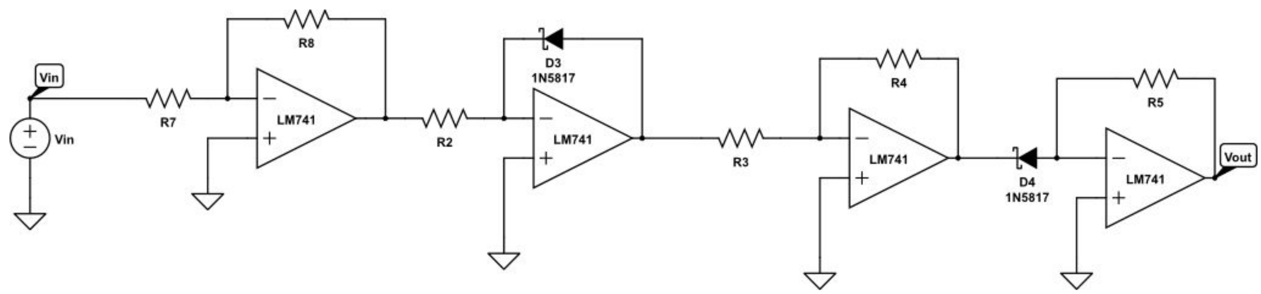

Figure 3: Squaring circuit schematic

Data Amplifier

Since the output of the adder is small (within the 3V range), it must be amplified before being passed into the sound generator in order to make differences between output voltage levels more evident. This can be done with an op amp with high gain.

Low Pass Filter

Sallen Key low pass filter using an LF353 op amp to remove unwanted high frequencies due to noise in the output. The appropriate values for the frequency cutoff will depend on the waveform produced by moving the accelerometer.

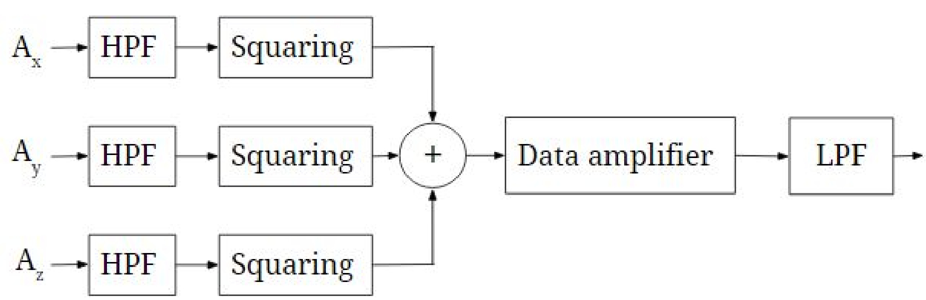

Figure 4: Squaring circuits and adder for x, y, and z axes

Oscillators

Variable sound effects can be created by modulating various signals together. A voltage controller oscillator (VCO), which generates a square wave, controls the frequency based on the input voltage – the faster the user swings the lightsaber, the higher input voltage and consequently the higher the pitch. The output frequency must lie within the audible range in order to be heard. This essentially acts as frequency modulation. This will also act as a carrier signal during amplitude modulation. The VCO will use two op amps, an integrator to generate a triangle wave, which is then passed into a Schmitt comparator (shown in Figure 5).

Phase shift oscillators (PSO) output sine waves with set frequencies. Setting the power supply of the phase shift oscillator to be proportional to the input signal will ensure that a higher input voltage will lead to a greater amplitude for the sinusoidal output – therefore, the faster the movement, the louder the volume. When the lightsaber is not in motion, the volume should be zero.

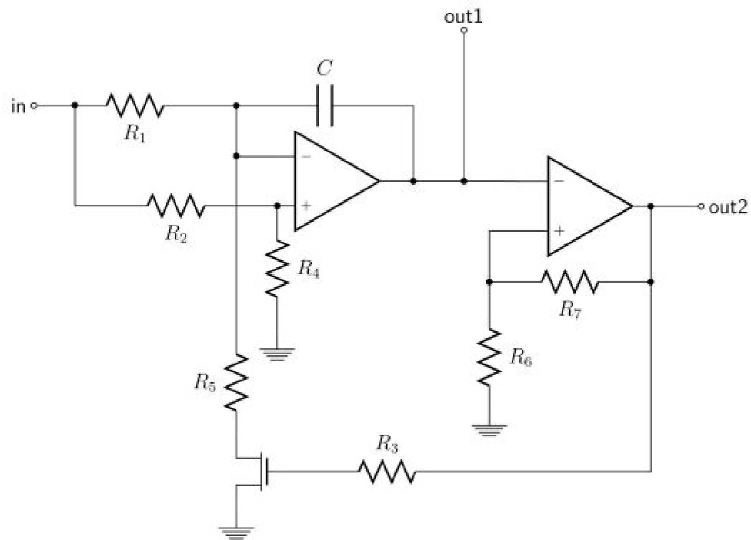

Figure 5: Voltage controlled oscillator

Amplitude Modulation and Adder

The signals produced by the oscillators will be modulated through amplitude modulation circuits to create more interesting waveforms. In order to generate signals that resemble the famous lightsaber sound effects, the Fourier transforms of audio data from sound files of the sound effects were generated in order to determine which frequencies to modulate together. Depending on the input voltage patterns, different sound effects will be combined in an adder.

Sound Amplifier

A class AB push-pull amplifier, which will have better efficiency and less crossover distortion compared to class A or B configurations, will be built to amplify the output signal to be audible through the speaker. Just like the sound generator, we would like to eventually be able to power this part by battery. The amplifier output will be sent to a speaker, which ideally will be small enough to be mounted to the base of the lightsaber.

Power Supply

Initially all the circuits will run from a 9V battery. As part of our stretch goals, the 9V battery will eventually be replaced by two AA batteries in order to make the module more accessible. In order to ramp up the voltage from the AA batteries to reach the original 9V, a boost converter with a switching circuit is necessary.

Components

- DE-ACCM3D Accelerometer
- LF353 Op Amps
- 2N3904 and 2N3906 transistors

- 2N7000 and ZVP410 mosfets
- Speaker
- Rod/lightsaber
- 9V batteries, AA batteries

Testing

Initially, the individual modules of the both the data acquisition and sound generation parts will be built and unit tested. These modules will then be integrated and tested to demonstrate sound effects in one axis. Once it is confirmed that the circuit works in one dimension, the other two axes will be incorporated.

Schedule

Deadline	Task
4/23	Demonstrate sound effects for one axis
4/30	Incorporate all three axes and refine sound effects (e.g. adding hitting noise)
5/4	Implement design for battery saving timer, and if time permits, stretch goals (using 2 AA batteries, mechanical device for turning on circuit)
5/7	Final testing and debugging
5/9	Project demo