E155 Final Project Proposal: Music Light Show

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Motivation:

Light shows are often used to enhance music but coordinating lighting with music is challenging to do on the fly, especially with a low-cost setup.

Goals:

Our overarching goal for this project is to design a system that automatically creates interesting lighting effects which are synchronized to a live audio input. Our subgoals include the following:

1. Read in Audio from a 3.5mm jack using an ADC.
2. Implement the FFT on the FPGA.
3. Implement an algorithm to produce lighting effects that are synchronized to some aspect of the music based on time and frequency information.
4. Communicate between FPGA and microcontroller.
5. Vary lighting using MCU based on FPGA input by selecting a pattern on a diffraction grating for a laser to shine through.

Design:

Digital acquisition is based on the simple and low-cost stereo audio PCM1808 ADC, which will communicate with our embedded system over an i2s interface. The FPGA will continuously perform windowed FFT functions, effectively computing the STFT sequentially. The output will be converted to a magnitude representation, and a digital filter will be applied to the output sequence (in time) that selects specific bins and an onset function. This onset function will be compared with a threshold value, and whenever a positive edge is encountered (e.g. the onset function rises above the threshold), the FPGA will increment a prescaler counter. When this prescaler is reset by overflow, the FPGA changes the selected pattern and reports this over a parallel bus to the MCU.

The MCU polls to find the pattern selection, and determines the angular range of the servo that corresponds to a laser shining through the specific pattern on the diffraction grating disk. It then drives a servo via PWM to within this angular range, slowly varying the angle to move the pattern. The laser circuitry and diffraction grating disk are taken from an existing laser light show product, and the diffraction grating disk is mounted on the servo.

Block Diagram:

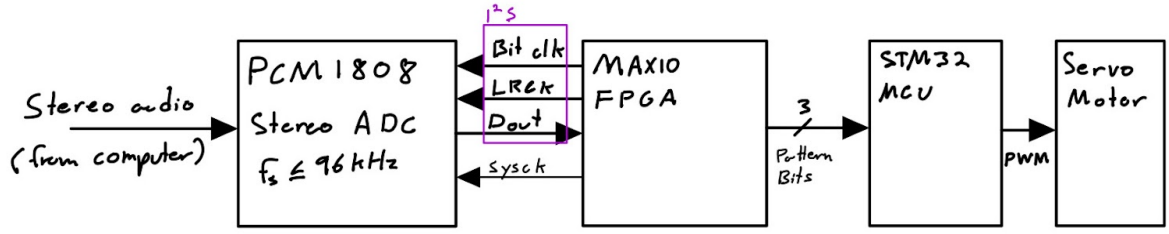

Figure 1: Hardware data-flow diagram. The PCM1808 ADC samples the audio and reports this to the MAX10 FPGA, which processes it and returns a "pattern selection" state to the MCU. The MCU determines the servo position given the pattern selection and drives the servo motor.

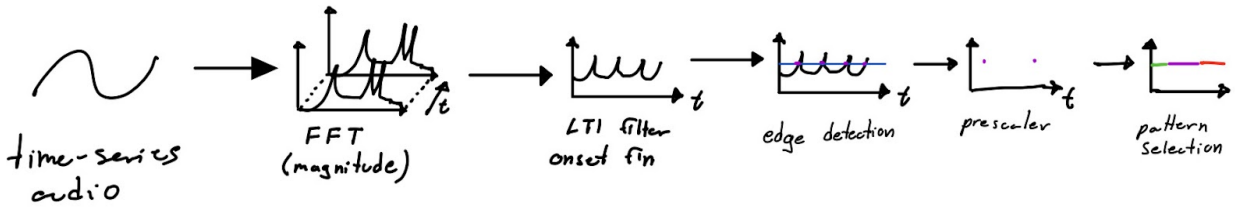

Figure 2: FPGA DSP data-flow diagram. An FFT is performed on the time-series audio, with magnitude output. An LTI filter selects relevant bins and calculates a novelty function. This is compared with a threshold to determine beat onsets, which, after a prescaler, turn into "pattern selection" state change impulses.

Budget:

Item	Cost
PCM1808	$2.23
CAP CER 1UF 50V 0805 (x2)	$0.374
CAP CER 0.1UF 50V 0805 (x3)	$0.396
CAP CER 10UF 25V 080 (x3)	$1.26
CONN RCA JACK MONO 3.2MM (x2)	$4.36
CONN JACK STEREO 3.5MM SMD (x2)	$1.88
CONN HEADER VERT 40POS 2.54MM	$0.73
Digikey Shipping	$4.99
JLCPCB boards + shipping	$8.98
Laser + Diffraction Grating	$20.99
Hitec HS-311 Hobby Servo	$13.94 (already owned)
Total	$46.19