

ECE4011/ECE 4012 Project Summary

Project Title	Electronics for Music Applications
Team Members (names and majors)	Chris Walds, EE Harrison Zhang, EE Jongheon Park, CmpE Justin Kelley, CmpE Kristyn DiGiovanni, CmpE Sriram Pulavarty, EE Yewon Kim, EE
Advisor / Section	Jennifer Hasler / A06
Semester	Semester/Year: Fall 2019 Circle: Either Intermediate (ECE4011) or Final (ECE4012)
Project Abstract (250-300 words)	<p>The purpose of this project is to design, build, and test configurable mixed-signal electronics for music application, specifically music synthesis. This project aims to create a portable, low-power music synthesizer using analog circuit elements. This fulfills the need for portable electronics that can generate accurate and clean audio signals. To achieve such music capabilities, computational efficiency and small size of circuitry will be important. A viable solution to this project will require a mixture of software and hardware; the main components of the system will include a peripheral device that interfaces with a MIDI shield, which will convert and feed input into a synthesizer circuit on the Field-Programmable Analog Array (FPAA).</p> <p>The FPAA is a mixed-mode system-on-chip that weaves analog and digital programmable and configurable blocks into a single fabric. The FPAA's utilization of analog computation allows for ultra-low power consumption (at around 1000x the energy efficiency vs. solely digital circuits) for applications in signal processing, machine learning, and neuromorphic computing. The FPAA's strengths coincide well with the design constraints of this project, and its configurability in different applications of signal processing allow highly customizable music synthesis blocks. The FPAA is programmed via RASP Tools, an interface which generates a switch-list of floating gates from block designs specified by the user. RASP Tools is then able to program this design onto the FPAA via USB and read the resultant data back. However, the FPAA can also interface with multiple other devices via USB, including an Android application that performs the programming and data analysis features of RASP Tools. This project will generate the necessary music synthesis circuitry using RASP Tools, then possibly use a portable Android application to program the design onto the FPAA and generate MIDI signals to synthesize audio.</p>

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<p>List codes and standards that significantly affect your project. Briefly describe how they influenced your design.</p>	<p>Since we want our synthesizer to be able to be controlled by already existing external sequencers, controllers, or DAWs (Digital Audio Workstation), our design needs to have MIDI (Musical Instrument Digital Interface), which is a standard for communication between electronic musical instruments. To implement MIDI, the smartphone that is interfacing with the FPAA synthesizer acts as a host sending MIDI data over USB with a proprietary or existing application. However to communicate external controllers through a 5-pin DIN connection, the synthesizer needs a passive circuit containing an opto-isolator and resistors, which is specified with a reference design on the MIDI specification..</p>
<p>List at least two significant realistic design constraints that applied to your project. Briefly describe how they affected your design.</p>	<p>For the application of a music synthesizer FPAA with smartphone or tablet support, we face design constraints in portability and power. While the FPAA model is small, we need to develop a compact interface for the device to communicate with a smartphone (via an app for example) over USB (OTG). The goal is for the device to view the FPAA as any other USB peripheral, but there have been challenges in the past with compatibility issues at the USB interface. The group is limited in the control of the interface at the master (controlling device) side due to the device’s pre-installed USB drivers. Therefore, the design must be adjusted at the FPAA side to ensure it behaves like any other peripheral USB device.</p> <p>While the device can be programmed with either a computer or smartphone, it is necessary for the smartphone to power the FPAA over USB if it’s expected to interface with USB. Before going further with the design, the group had to verify the board’s power consumption to ensure that it could be compatible with a standard USB interface.</p>
<p>Briefly explain two significant trade-offs considered in your design, including options considered and the solution chosen.</p>	<p>One significant tradeoff associated with this project is that between performance (speed and sound quality) and energy efficiency. Since there is a possibility that the music synthesizer system will interface with an Android smartphone or tablet, the design must not be energy intensive. However, lower energy targets may force the FPAA board’s microprocessor to operate less efficiently, resulting in slower conversion of the MIDI Shield board’s output data to analog signals. Additionally, they may limit the maximum amplitudes allowed for the waveforms generated by the synthesizer, providing a bottleneck on the volume of any output audio.</p> <p>Another significant tradeoff associated with this project is that between low level configurability and ease of use. The values of various control voltages (CVs) for the voltage controlled oscillator (VCO), amplifier (VCA), and filter (VCF) components of the music synthesizer may be chosen as user-defined inputs to the circuit or as predetermined values. For example, the VCA may take in an attack-decay-sustain-release (ADSR) envelope to produce a “plucked string” sound, or it may take in other user-defined envelopes. Allowing users to define specific CVs allows for greater low-level control, for these CVs can impact the types of sounds that can be synthesized. Using predetermined values for some CVs (such as only allowing an ADSR envelope), however, would limit the types of sounds that could be synthesized but would result in a smaller learning curve for new users if the music synthesizer system entered the market.</p>

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<p>Briefly describe the computing aspects of your projects, specifically identifying hardware-software tradeoffs, interfaces, and/or interactions.</p> <p><i>Complete if applicable; required if team includes CmpE majors.</i></p>	<p>There are two major computing aspects associated with this project:</p> <ul style="list-style-type: none"> - Appropriate coding of the FPAA. - Interfacing the FPAA with the Android application. <p>FPAAs utilizes RASP Tools which is available on a preconfigured virtual machine. RASP Tools takes in the desired user block design, creates a switch-list of floating gates, then exports the compiled program to the hardware via a USB connection. RASP reads resultant data back to the host machine through the USB cable using a variety of interfaces including the desired Android application.</p> <p>Depending on progress made through the semester, a possible goal is to interface the synthesizer to an Android application. If this is tackled, the Android application will perform data analysis features of RASP Tools for an easy user interface. Major functionality of this aspect includes synthesizing the MIDI signals through communication with the programmed FPAA on the USB interface.</p> <p>A MIDI shield will protect the FPAA circuit from voltage spikes caused by the continuous flow of MIDI data from the peripheral device.</p>
<p>Leadership Roles (ECE4011 & Forecasted for ECE4012) (NOTE: ECE4012 requires definition of additional leadership roles including:</p> <ol style="list-style-type: none"> 1. Webmaster 2. Expo coordinator 3. Documentation 	<ol style="list-style-type: none"> 1. Team Coordinator - Justin 2. Hardware Specialist - Yewon 3. Software Specialist - Kristyn 4. Documentation - Sriram 5. Design Coordinator - Jongheon 6. Expo Coordinator - Chris 7. Webmaster - Harrison
<p>International Program: Global Issues (Less than one page) (Only teams with one or more International Program participants need to complete this section)</p>	<p>N/A</p>