## **Project Title Electronics for Music Applications Team Members** Chris Walds, EE Harrison Zhang, EE (names and majors) Jongheon Park, CmpE Justin Kelley, CmpE Kristyn DiGiovanni, CmpE Sriram Pulavarty, EE Yewon Kim. EE **Advisor / Section** Jennifer Hasler / A06 Semester Semester/Year: Spring 2020 Final (ECE4012) The purpose of this project was to design, build, and test configurable mixed-signal **Project Abstract** electronics for music application, specifically music synthesis. We aimed to create a (250-300 words) portable, low-power music synthesizer using analog circuit elements. Changes were made to our design solution following campus closing due to the COVID-19 virus. Prior to the shift to remote development, our design consisted of a mixture of software and hardware; the main components of the system would have included a peripheral device that interfaces with a MIDI shield, which would convert and feed input into a synthesizer circuit on the Field-Programmable Analog Array (FPAA). Following the shift to remote development, our group had to change our design solution to ensure that we had an achievable goal given the constraints that come with working remotely. This included elimination of certain hardware (peripheral devices) and simplification of music synthesizer design. 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 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 was 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. Our design included both additive (summing amplifier adds multiple harmonic waveforms) and subtractive synthesis elements (multiplier used to shape wave) designed in RASP Tools. The FPAA is able to support the design, compilation, and execution of multiple analog circuit designs simultaneously. By taking advantage of these features, we were able to design a simple music synthesizer using FPAA technology.

## **ECE 4012 Final Project Summary**

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List <b>codes</b> and <b>standards</b> that significantly affect your project. Briefly describe how they influenced your design.	The following constraints were applicable with the original project design: Since we wanted our synthesizer to be able to be controlled by already existing external sequencers, controllers, or DAWs (Digital Audio Workstation), our design needed to support MIDI (Musical Instrument Digital Interface), which is a standard for communication between electronic musical instruments. This is possible via decoding code written in Assembly and running on the FPAA's microcontroller. However to communicate with external controllers, the design must support UART communication protocol. This is made possible via serial-to-parallel ICs and proper interrupt handling by the microcontroller.
List at least two significant <b>realistic</b> <b>design constraints</b> that applied to your project. Briefly describe how	Because the FPAA board only has a certain number of circuit elements built-in, our design was constrained by those elements. For example, the FPAA does not have many pure resistive elements (although there is a voltage divider) but it does have several transistors and OTAs, so our oscillator and amplifier designs made use of those elements.
they affected your design.	Another constraint was the size of the FPAA's configurable analog blocks (CABs). While the team wanted to program many of the synthesizer's components in MacroCAB blocks rather than the higher level but less configurable MacroBLIF blocks, the limited number of components in the CABs meant that the team often had to use MacroBLIFs.
	Additionally, due to the configurable nature of the FPAA technology, our design originally consisted of multiple oscillator banks being added and modified. This allowed for a hierarchical design with multiple unique computing elements designed in RASP Tools.

Briefly explain two significant trade-offs considered in your design, including options considered and the solution chosen.	One 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) and amplifier (VCA) 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 or even a constant voltage. 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 a constant voltage), 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. For example, we ultimately decided not to use an ADSR envelope, and we did away with one of our initial components - the VCF, which would have allowed us to vary the frequency and produce a vibrato effect. Another significant tradeoff associated with this project is that between technology compatibility and performance / development time. One of the central decisions made in this design was to forgo the conversion of MIDI data as an input to the device. Allowing users to plug MIDI instruments into the FPAA would have made the product more accessible. However, due to the necessary logic level conversion, UART interfacing, and microcontroller programming (to derive control voltages from the MIDI inputs), the performance of the synthesizer might have suffered, and the input-to-sound latency would have increased. Additionally, development time would have increased, especially in the midst of COVID. As a result, the team decided to implement a less technologically compatible approach that would still produce a range of sounds.
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Briefly describe the computing aspects of your projects, specifically identifying hardware-software tradeoffs, interfaces, and/or interactions. Complete if applicable;required if team includes CmpE majors.	<ul> <li>Before the COVID-19 Pandemic, the original design goal was to interface the synthesizer created to an Android application or a MIDI device. This was not achievable after the move to distance learning, so the computing aspects involved are solely that of programming the FPAA using RASP tools.</li> <li>FPAAs utilizes RASP Tools which is available on a preconfigured virtual machine (https://hasler.ece.gatech.edu/FPAAtool/index.html). 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.</li> </ul>

Leadership Roles	1. Team Coordinator - Justin
(ECE4011 & Forecasted	2. Hardware Specialist - Yewon
for ECE4012)	3. Software Specialist - Harrison
(NOTE: ECE4012	5 Design Coordinator - Jongheon
requires definition of	6. Expo Coordinator - Chris
additional leadership	7. Webmaster - Kristyn
roles including:	
1.Webmaster	
2. Expo coordinator	
3. Documentation	
International Program:	N/A
Global Issues	
(Less than one page)	
(Only teams with one or more	
International Program	
participants need to complete	
this section)	