musictronics

January 22, 2010

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Project Proposal for an Electric Guitar Effects Combiner

Dear Dr. Rawicz,

The attached document, *Functional Specifications for an Electric Guitar Effects Combiner*, outlines the functional specification for our ENSC 440 (Capstone Engineering Science Project) project. This project is set to make combining the effects of an electric guitar for a professional guitar player easier and more efficient.

This document outlines the required functional specifications for the proof-of concept design as well as the final production. This document will be used by team members as a milestone marker to monitor our progress in the semester as well as a scheduling tool for the project manager.

Musictronics team is established by three innovative and passionate engineers: Kianoush Nesvaderani, Amanueal Heilegio, and myself, Gondang Prabowo Yudo. If you have any questions or concerns about our proposal, please feel free to contact me by e-mail at gpy1@sfu.ca.

Sincerely,

Gondang Prabowo Yudo
President and CEO
Musictronics

Functional Specifications for

Electric Guitar Effects Combiner

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EXECUTIVE SUMMARY

For a professional guitarist or burgeoning amateur trying to make it, the best kinds of effects to use are the stompboxes effects. Why? They are easy to use, a lot of variation, sounds amazing, and cheap. And since the stompboxes comes in many different types (distortions, flanger, pitch shifting, etc) it is very common for a guitarist to possess more than 6 stompboxes pedals. This becomes a problem in live performances. Especially if you have to turn on multiple stompbox effects in combination to get a certain tone.

To alleviate this issue we decide to design a device that can combine the stompboxes using digital signal switching. We are going to implement the switching mechanism in FPGA board and thus the whole system will be digital and operating close to real time. The device would also have the ability to combine multiple stompbox effect in a single step, eliminating the need for guitarist to multitask during live performances.

Current technologies for combining stompboxes effects are inflexible and impractical. On solution is to get the Morley ABY switch. This switch allows you create 2 different stompbox effect loops. And it is clear that the limitation on this device is the amount of effect combination it can produce. Another solution is to buy a multi-effect devices (BOSS GT-10, Line 6, etc), but this solution has several drawbacks. One is the drop in sound quality since its well documented that multi effect produces a “weaker” output thann the stompboxes. Another drawback is the cost, to buy a really good multi-effect devices can cost up to $3000.

Musictronic consist of 3 4th and 5th year students from SFU with different technical background as well as experience. We have considerable knowledge in Hardware Design, Software design, as well as Real-Time System to successfully design and Integrate the Device. The proposed project has an overall budget of $903.A detailed 13 week schedule has been constructed with April 9th as the proposed date for completion.

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GLOSSARY

ADC	Analog to Digital Converter
DAC	Digital to Analog Converter
FPGA	Field Programmable Array
MAC	Multiply/Add Circuit

1.0 INTRODUCTION

The Combinator requires the construction of a system that combines the analogue effects for an electric guitar, provided by a series of stompboxes, and delivers the effects via a series of preset buttons. The electric signal from the guitar, through the designated effects, will be routed by a digital switching circuit. Since every stompbox has its own signal loop, the preset buttons will be constructed with a control circuit giving the user flexibility and ability to store multiple combinations of stompbox chain. This document describes the proposed functional specification requirements for the Combinator.

1.1 Scope

This document describes the requirements needed for a proof-of-concept design of the Combinator along with additional requirements for the final production. These requirements are needed to properly assess design goals and ensure that the Combinator's functionality is aligned with our target market's usability goals.

1.2 Intended Audience

Musictronics members are the intended audience for the functional specifications. The project manager will use this document as a guideline to observe completion of goals, organize scheduling, and assess the level of effort needed. The requirements will be used by the team members as goals for the product design along with a guideline for functionality testing.

1.3 Classification

In order to identify and categorize each functional requirement, the following convention is used:

R[X-Y] The Functional Requirement.

The 'X' denotes the number of the functional requirement for future referencing and the 'Y' specifies the requirement category which falls into one of the following two:

I – Requirement present in the proof-of-concept and final production.
II – Requirement present in the final production only.

2.0 SYSTEM REQUIREMENTS

This section will provide detailed specifications and requirements of the overall system. The functional requirements will be divided into 5 sections:

1. System Overview
2. Analog to Digital Converters (ADC)
3. Multiply/Add Circuit (MAC)
4. Analog Configuration Circuit
5. Casings

Each section will give some general and component specific functional requirements.

2.1 System Overview

Figure 1 below shows, in more detail, the data flow between the components inside the Combinator. Furthermore we also provide the outline of the system requirements.

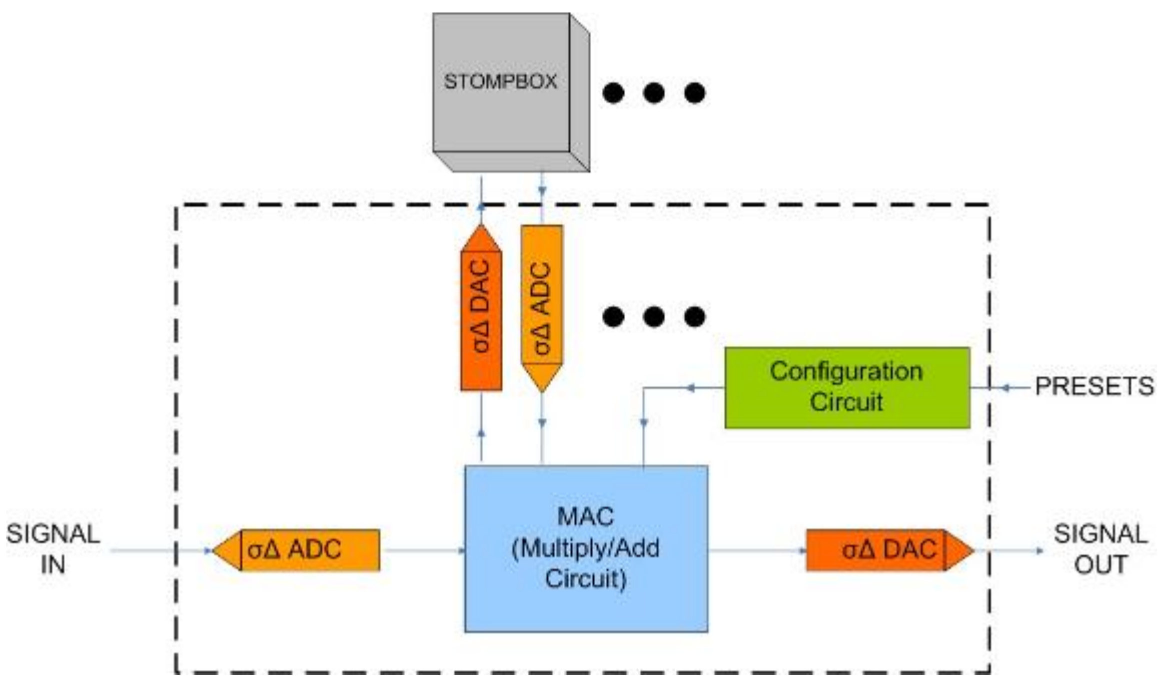

Figure 1 - System Overview

Physical Requirements

R[1-I] The Combinator should 16”(L) x 8.5”(W) x 3”(H).

R[2-I] Conductive Paint must be applied outside and inside the casing to prevent electrical interference from other electrical equipment.

R[3-I] The system can house up to 4 Stompbox effects and 5 different preset combinations.

Electrical Requirements

R[4-II] The Combinator shall use minimum power to ensure reliable operation and prevent any overheating of components.

R[5-I] The Combinator shall be powered by a 12 V DC adaptor.

Performance and Reliability Requirements

R[6-I] The system should not have any delay between the input and output.

R[7-I] The output sound should be >95% in quality compared to the input sound.

Reliability

R[8-I] The System shall be able to withstand constant stepping as well as vibration from other equipments.

Usability Requirements

R[9-I] The user interface shall be intuitive, simple, and easy to use by the user.

2.1 Converters

This component is responsible to convert analog data to digital data to enable processing on the FPGA board (MAC). In our system we use 2 types of converters, the ADC (Analog-to-Digital Converters) and DAC (Digital-to-Analog Converters) but essentially both have the same characteristics in terms of requirements. Hence in this section the requirements defined are applicable for either the ADC or DAC.

General Requirements

R[10-I] The converters have to sample every 500ns to ensure no delay occurring at the output.

Physical Requirements

R[11-I] For digital data (DAC) the converter will use the 3-wire SPI interface as the input and ¼" plug as the output.

R[12-I] For analog data (ADC) the converter will use the ¼" plug as the input and 3-wire SPI interface at the output.

Electrical Requirements

R[13-I] The Converters shall not consume more than 50mW of power.

Operating Conditions

R[14-I] The converters shall be able to operate between 0°C to 85°C.

R[15-I] The converters have to be able to work properly in constant vibration.

Reliability and Durability

R[16-I] The converters shall have an operational life span of 5 years.

R[17-I] The sampling error shall be below 2% to maintain high quality digital sound.

2.3 Multiply/Add Circuit

This circuit is responsible for routing and blending the digitized input signal into the stompbox effects. The circuit is controlled by the “Configuration Circuit”. The configuration circuit will tell the MAC in binary how the routing suppose to be in a particular preset. The MAC will be implemented on and FPGA board.

General Requirements

R[18-I] The MAC circuit must support the 3 wire digital interface from the Digital Converters.

R[19-I] The MAC circuit must also support the analog connection from the configuration circuit.

Electrical Requirements

R[20-I] The MAC circuit must be powered inside the Combinator by a power supply

R[21-I] The MAC circuit must be powered by 6 V or 12 V power supply

Physical Requirements

R[22-I] The MAC circuit shall be protected by a cushion insulation to ensure longer durability.

FPGA requirements

R[23-I] Only 70% of the FPGA coding space will be used to enable future upgrades.

R[24-I] VHDL will be used as our primary FPGA programming language.

R[25-I] Communication with other digital components shall use the 3 wire protocol.

R[26-I] Communication with analog components shall use the standard analog I/O on the FPGA.

2.4 Analog Configuration Circuit

Analogue configuration circuit's main functionality will be to read the analogue inputs from the stompboxes and control the presets for the user. Our system is adaptable to any combination of stompboxes (up to four), and the user is free to connect each preset button to any stompbox of their choice. After assigning the analogue inputs to the presets, the configuration circuit will provide the MAC with the required inputs (effects) as the guitar player presses the buttons and sends signals through the MAC while playing.

General Requirements

R[27-I] The circuit shall be assembled on a PCB

R[28-I] The circuit shall read up to five analogue inputs at the time.

Physical Requirements

R[29-I] The circuit board shall be as small as possible, most likely around 106mm by 98mm.

R[30-I] The circuit board shall be connected to the stompboxes via ¼ inch connection.

Electrical Requirements

R[31-I] The circuit board shall work with a 3.0 to 3.6 V power supply

R[32-I] The circuit board shall not consume more than 2500mW of power

Operating Conditions

R[33-I] The circuit board shall be able to withstand and tolerate high temperature for the purpose of long time performances.

Reliability and Durability

R[34-I] The circuit board shall send the inputs to the MAC with a maximum error of 2%

R[35-I] The circuit board shall have life cycle of 5 years.

2.5 Casings

The main purpose of casing is to gather all the parts into a simple yet stylish box and represent the final product in a fashionable way. Since our target customers are mainly professional musicians, the casing should be as classy and neat as possible. The casing will provide the user with the preset buttons on the top and will assign the active presets with flashing LEDs. The presets themselves are color-coded, and each color is related to a specific ¼ inch plug connected to a specific stompbox.

General Requirements

R[36-II]The casing shall be black metallic in color

R[37-I] The casing shall have four ¼ inch plugs for the four stompboxes' inputs

R[38-I] The casing shall have flashing LEDs for the active presets

Physical Requirements

R[39-II]The casing shall be made of steel aluminum

R[40-II]The casing shall be painted with inductive paint

R[41-I] The casing shall be in dimensions 16"(L) x 8.5"(W) x 3"(H)

Electrical Requirements

R[42-I] The casing shall be powered with a cord adaptor of 12 V DC

Operating Conditions

R[43-I] The casing shall be able to withstand over heat for hours for the duration of live performances.

R[44-I] The casing shall be able to tolerate robust vibrations from the speakers and the live c crowd

Reliability and Durability

R[45-I] The casing shall have a life cycle of 5 years.

3.0 SYSTEM TEST PLAN

We will test and verify each component of the Combinator to ensure full functionality. Our proposed system test plan includes three phases:

1. Testing each individual part (convertors, MAC, configuration circuit, casing)
2. Testing each component (combinator and stompbox)
3. Complete integration

3.1 PHASE 1 – INDIVIDUAL PARTS

Convertors

There are four convertors in total in the Combinator, two DACs and two ADCs. We will first test each convertor separately to ensure if they work properly. We are going to send analogue and digital signals to the convertors randomly and observe if they convert the signals. Then, after it has been verified that the individual convertors work correctly, we will add the convertors to the system and perform similar tests. Besides, we will measure and specify the length of the signals to ensure that it is within the limit of the convertors.

Multiply/Add Circuit

The main functionality of the Combinator is tested here. For the Multiply/Add Circuit (MAC), the first step is to make sure all the VHDL coding applied to our FPGA boards is debugged. We are going to divide the coding into two major parts and work on two identical FPGA boards. After it has been verified that all the codes run properly without any bugs or errors, we will take the MAC to the system, connect it with the convertors and the configuration circuit. Then, we will test if the codes written can detect the signals and combine them.

Analogue Configuration Circuit

In order to test the configuration circuit, we are going to use a bread board and electric switches to observe if the circuit is capable of sending the signals using switches. After it has been verified that the circuit is able to send analogue signals by pressing switches, we will connect the circuit to the system and test again if it can detect the signals from the stompbox too and is able to call the right signal when the relevant preset button is pressed.

Casing

The casing will be tested in materials before being used. We will first test if our metal case is painted with an inductive paint. Then, we will make sure if the size of the preset connectors can fit our system. In addition, we should also make sure if the size of the case can hold the weight and the size of our system.

3.2 PHASE 2 – INDIVIDUAL UNITS

We will be combining all the individual parts in this stage and assemble our final product. Although stompbox is not a part of this project, and it is not a product of Musictronics, but it can applied as one of the components of this project that needs to be tested along with the Combinator. In this part, we are going to connect the stompboxes to the combinatory. After, we are going to press the preset buttons on the casing and observe if the right LED flashes when the relevant preset is pressed. Finally, we will connect the electric guitar to the combinatory and will test the presets one by one with the same stompx, just to verify if the both components work properly together.

3.3 PHASE 3 – COMPLETE SYSTEM

We will be testing the complete functionality of the Combinator in phase 3. In this case, we will connect up to four stompboxes to the Combinator. Then, using a guitar player, we will test each preset individually first. Finally, we will combine the preset by pressing the buttons at the same time and test if the Combinator can combine all the effects correctly.

4.0 CONCLUSION

This document has outlined the functional specifications for the proof-of-concept and final production of the Combinator. Three phases were introduced in the proposed test plan, which include testing of individual parts, then individual units, and finally the complete system. Phase one is where we are currently standing, testing of individual parts, and we are confident that the functional requirements for the proof-of-concept, labeled R[X-I], will be completed by the proposed date of April 9, 2010.