



Design Specifications for

Electric Guitar Effects Combiner

Project Team: Gondang Prabowo Yudo

Kianoush Nesvaderani

Amanueal Hailegiorgis

Submitted To: Dr. Andrew Rawicz

Dr. Steve Whitmore

Contact Person: Gondang Prabowo Yudo

gpy1@sfu.ca



March 11, 2010

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

Re: ENSC 440 Design Specifications for an Electric Guitar Effects Combiner

Dear Dr. Rawicz,

The attached document, *Design Specifications for an Electric Guitar Effects Combiner*, outlines the design 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 design 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



EXECUTIVE SUMMARY

This document outlines the development and design pertaining to the proof-of-concept model of the Combinator. We will discuss design considerations for the functional specifications marked as XX-I in our *Functional Specifications for an Electric Guitar Effects Combiner* document.

We will also provide justifications for the choice of components and algorithms that will be implemented in the final production. The proof-of-concept model includes the Combinator box and the power supply. The box consists of 4 buttons on top, each of which representing a preset with four pin connections. For the proof-of-concept design, waterproof material has been chosen for casing of the whole box. The Combinator is made up of three main parts: convertors, configuration circuit, and the arithmetic unit (MAC). The stompboxes, each representing a type of effect, are connected to the pin connections of each preset. When a button is pressed, the ADC converts the analogue signals to digital. The configuration circuit receives these digital signals, detects the active ones, and sends them to MAC. From there, MAC combines these digital effects and sends them to DAC. Finally, DAC converts the digital signal to analogue and sends the output to speakers. The user will have the option to choose between 4 sets of presets, each of which can be connected to four different stompboxes.

Multiply/Add Circuit mechanism is the primary technology regarding the Combinator. We discuss difficulties arising from programming MAC and provide a general algorithm for our design. Flow charts are presented to illustrate the process of each component. Finally a system test plan is presented to ensure proper functionality of the Combinator. The proof-of-concept model is expected to conform to these design specification by the scheduled completion date of April 16th, 2010.



TABLE OF CONTENTS

Executive Summary.....	ii
Glossary.....	iv
1.0 Introduction.....	1
2.0 System Specifications.....	1
3.0 System Overall Design.....	2
4.0 Multiply/Add Circuit.....	5
5.0 Converters.....	7
6.0 Configuration Circuit.....	8
7.0 System Test Plan.....	11
8.0 Conclusion.....	12
9.0 References.....	12

GLOSSARY

FPGA	Field Programmable Gate Array
MAC	Multiply/Add Circuit
ADC	Analog to Digital Converter
DAC	Digital to Analog Converter
GIO	General Input and Output
DIP	switches – Dual In-line Package Switches
MUX	Multiplexer
Stompbox	Individual Analog Guitar Effect



1.0 INTRODUCTION

The Combinator entails the construction of a music box that can combine the analogue effects of the electric guitar for professional guitar players. The device includes four preset buttons, each of which can be connected to four stompboxes. Each stompbox represents a different kind of effect; thus, the guitar player can connect up to sixteen different effects to the Combinator and use up to four of these effects at a time. When pressed, the related preset gets activated and passes the signals to the convertors so the signals get converted to the value bits of 0 and 1. Then, the configuration circuit detects these value bits and passes them to the MAC. On this stage, MAC reads the values, combines them together, and passes the combined signal values to the convertors. Finally, the convertors convert the value bits to the signals again for the speakers to output the sound.

1.1 SCOPE

This document outlines the design specification needed to satisfy the requirements in the *Functional Specification for an Electric Guitar Effects Combiner*. The requirements outlined in this document pertain to the proof-of-concept design as well as a portion of the final production (labeled as R[X-I] in the aforementioned document). Detailed explanation of each component of the Combinator is presented in order for the reader to gain a full perspective of the project.

1.2 INTENDED AUDIENCE

The intended audiences for the design specifications are the members of the Musictronics Inc. team. This document will be used as a guideline to ensure that all the intended functional requirements have been met. Also, the team members will carefully follow the proposed test plan to ensure accurate and proper operation of the system.

2.0 SYSTEM SPECIFICATIONS

The combinatory will only consist of the box itself and power supply. Each combinatory will be made of ADC and DAC convertors, configuration circuit, and the MAC. The ADC convertors first gather the analogue signals from the stompboxes, convert them to digital values, and pass them to the configuration circuit. At this point, the data will be analyzed for selection and stored into the buffer to be passed to the MAC. The MAC will do the arithmetic, and combines the signals. The user will be able to connect up to four stompboxes to each preset and select from four different presets only by pressing the desired button.

3.0 Overall System Design

This section will provide high level explanation of the complete system. It also provides explanation about components that are common for all the parts involved. A more detailed explanation about the parts inside the system is provided in the section following.

3.1 Mechanical Design

Several conditions have to be taken into consideration when we design the packaging of the overall system. The first condition is that the casing has to be robust enough to sustain constant stepping in live performances as well as lightweight for mobility. To comply with this requirement we decide to use a diecast aluminum casing. The aluminum material is hard enough to be robust and light enough to maintain mobility. The shape of our final product will look like *figure 3.1* below.

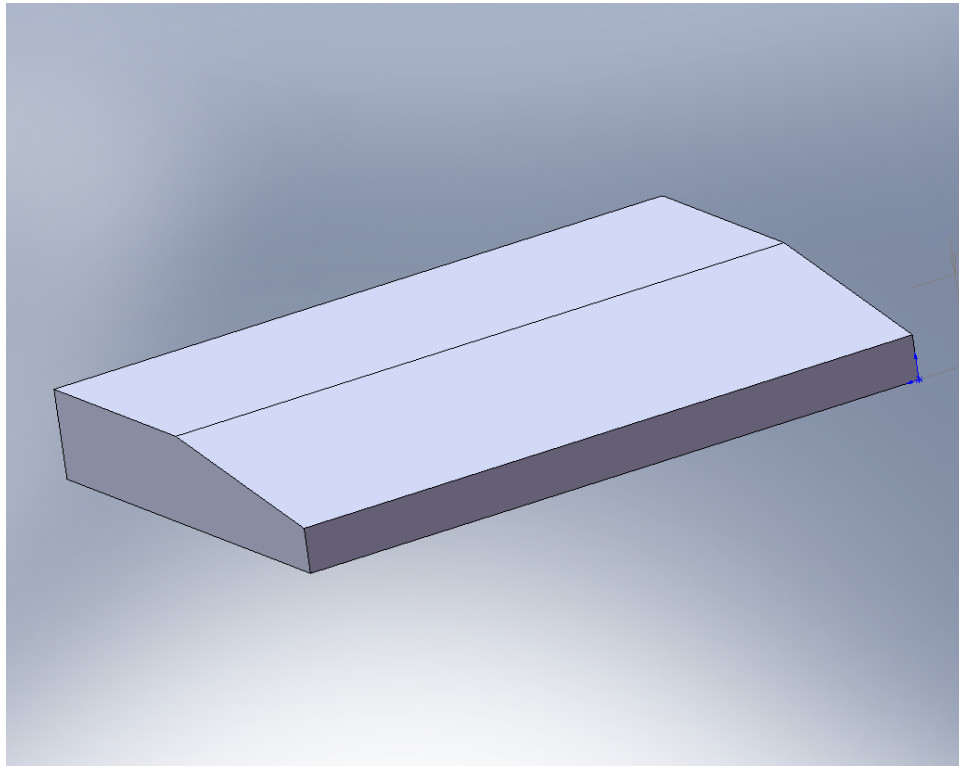


Figure 3.1 - Casing Design

Another consideration is electrical interference from other electrical equipment can disturb our component. To alleviate this we need to paint the casing with conductive paint. To further increase

the protection of our product we also plan to fill up any openings on the casing with silicon to waterproof it.

The last consideration we discuss for our product is the user interface. We need to come up with an intuitive user interface to increase usability from the user's point of view. **Figure 2** below shows our design for the user interface. We use a standard stomp switches for the preset button and a DIP switches for the FX chain configuration. The preset button will be located on the tilted side of the casing and the FX chain configuration is on the flat side of the casing.

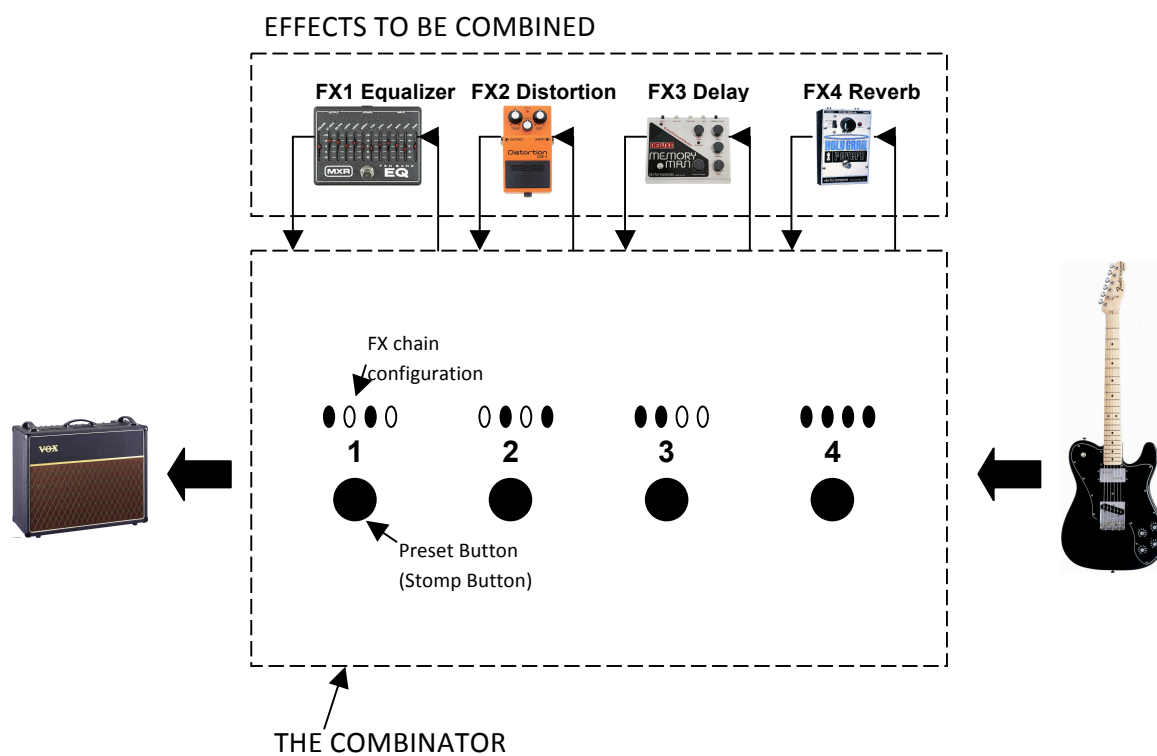


Figure 3.2 – User Interface Design

For the product to interface with the guitar, stompboxes and amplifier were going to use the ¼" connector.



Figure 3.3 - 1/4" Connectors male and female

3.2 High Level System Design

This section will provide a high level overview of the system design. Figure 4 below shows the relationship between parts in our system as well as the input and output.

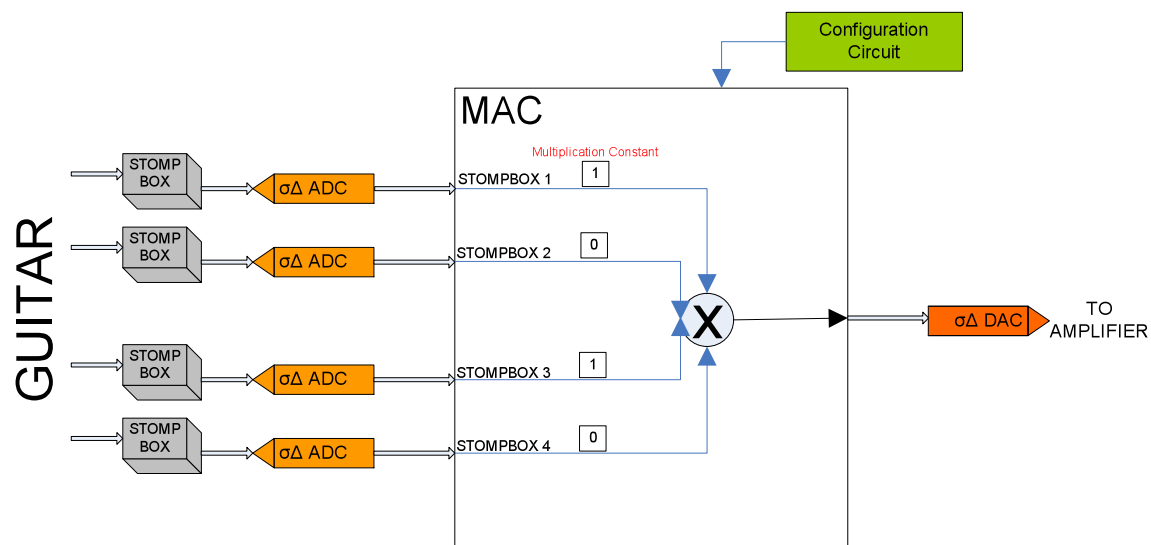


Figure 3.4 - High Level System Diagram

The system input is the analog signal from the guitar. The analog signal is then converted to digital using ADC's to enable processing in the MAC circuit. The configuration circuit acts as a control system to the MAC providing the circuit with Multiplication constants. This Multiplication constant will determine how many of the stompboxes effect had to be combined. The configuration circuit

itself depends on the preset pressed by the user and the fx chain configuration switches. After combining is done the output signal is then converted back to analog before reaching the amplifier.

4.0 Multiply and Add Circuit

The Multiply and Add Circuit (MAC) is responsible for combining the digitized signal coming from the ADC's. The MAC is controlled by the analog configuration circuit. The analog configuration circuit will tell the MAC by means of binary how many effects are to be combined when a preset is turned on.

4.1 FPGA

For the MAC component we decide to build it using Altera DE 2 FPGA board is to enable routing and combining in digital format. Combining in digital is an easy task; we just need to multiply the digital signal we intend to combine hence the name Multiply and Add Circuit. The circuit will have 2 states BYPASS and COMBINE. The BYPASS state is the initial state and it occurs when the device is on but no preset button is pressed (preset = 0), in reality this state would output the original signal from the guitar into the amplifier. The COMBINE state is activated if a preset button is pressed (preset = 1), this is the state where combining occurs.

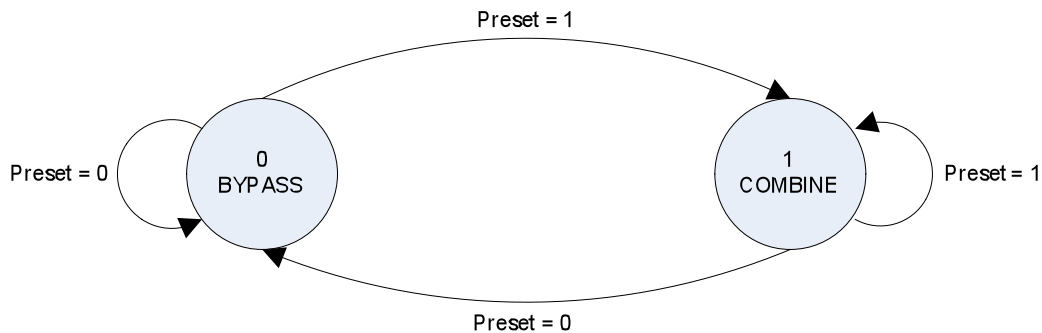


Figure 4.2 - MAC States

We will use the 2 GIO 40 pins extension headers in the DE2 FPGA board to communicate with the analog configuration circuit and the converters. The Configuration circuit is responsible for supplying the correct Multiplication constant for each stompbox. If the constant is “0” it means that the particular stompbox are not used. The constant is the one that tells the MAC which effects need to be blended. Figure 2 below shows a high level diagram of what’s inside the MAC. For the case in figure 2 you can see that stompbox 1 and 4 have a multiplication constant of “0” whereas stompbox 2

and 3 have a multiplication constant of “1”. Hence the output sound will only be the combination of the sounds produce from stompbox 2 and 3.

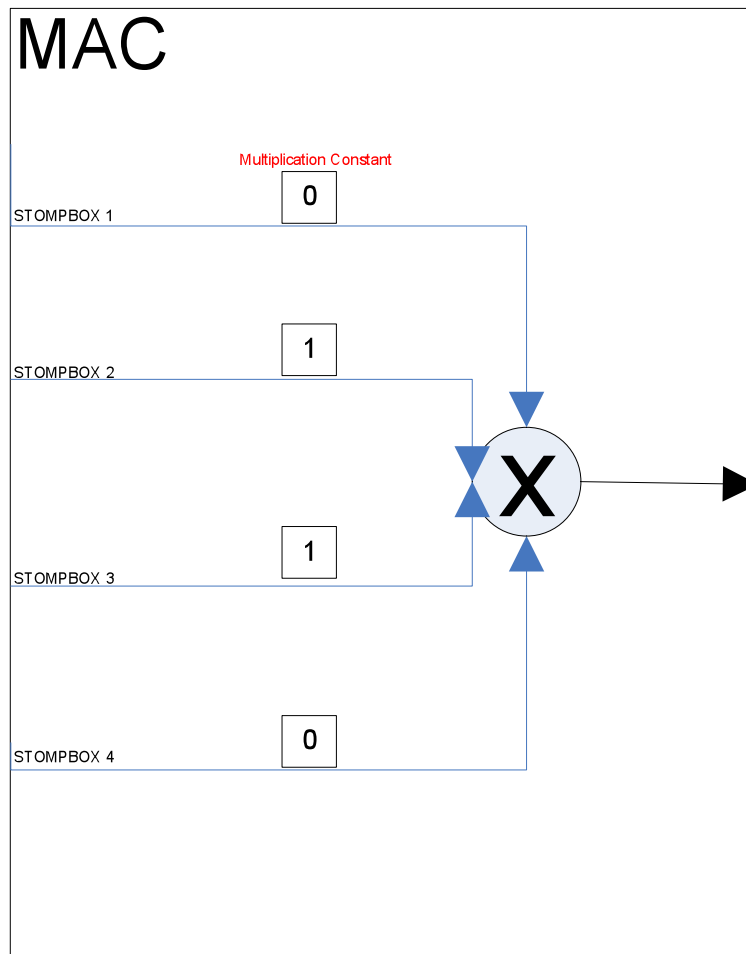


Figure 4.1 - Inside the MAC

5.0 Converters

5.1 Input Signal

For starters, the guitars output is fed into the Analogue Digital Converter. This converter has a high sampling rate and requires minimal power. Our initial approach was to use the DE2's Wolfson WM8731 audio CODEC in order to achieve the analogue-digital conversion. However, due to the complexity and high demand of this product, we will use in its place, an external analogue to digital converter with high resolution. In addition, for this project, we will design an Analogue to Digital Converter buffer, which will take the digital input received from the Analogue Digital Converter and buffers it into our effect combiner.

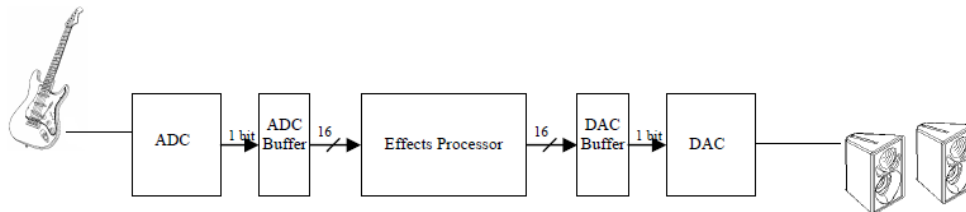


Figure 5.1

5.2 Output Signal

The output produced from the ADC buffer is fed into the effect combiner, which comprised of logical circuits.

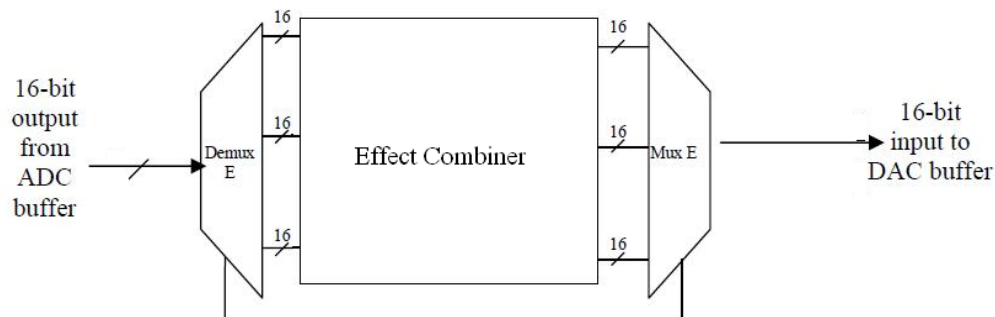


Figure 5.2

Once the desired effects have been added, the data is re-serialized out to the DAC through the DAC buffer. We will be making use of the DE2's audio CODEC.

6.0 Configuration Circuit

The main functionalities of the configuration circuit module for the Combinator can be described in three steps:

- Receive the signals from the presets when they are pressed
- Detect the signals and create an output
- Communicate with MAC

For these purposes, we have decided to build and use up to four 4:1 multiplexers and a buffer assembled on a circuit board. The general mechanism is for each MUX to read an input from each preset at a time, summing the bits of all presets into 4 bits for the inputs of one MUX. For example, the first MUX will read the first bits of all four presets. Then, the output of each MUX gets stored in the buffer where a 4 bit value gets created each time a button is pressed. From there, the MAC will read these 4 bit values to know which effects need to be combined.

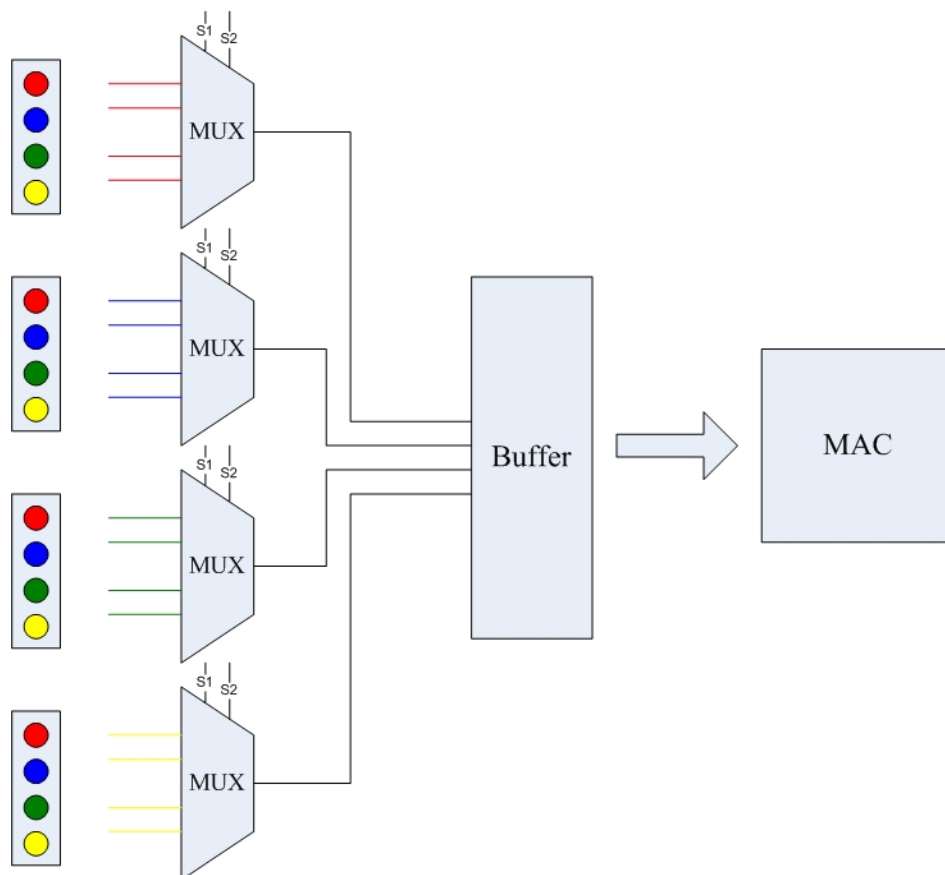


Figure 6.1 – The Block Diagram of Configuration Circuit

In fact, if a preset is pressed, the stompboxes connected to the preset gets activated, each of which assigning a value to each colourful pin as shown above. In this case, all the other pins related to the other presets have the value 0. Thus, when going to the multiplexers, only the bits from the activated preset pass through.

6.1 4:1 Multiplexer

Figure 2 shows the schematic of the 4:1 multiplexer (MUX), which is implemented by three 2:1 MUX modules connected in a tree structure. The input of all data streams (CH1 - CH4) are generated by the stompboxes connected to each preset. A 2.5 GHz clock source is connected to generate the desired speed of value passing. [1]

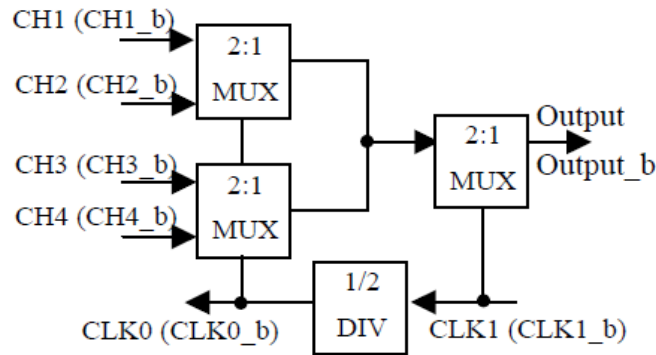


Figure 6.2 – The Schematics of 4:1 MUX

In order to pass the right signal, after passing the first stage, the inputs get narrowed down to two, one of which is the active one. At the second stage, the selection signals determine which input passes through. In order to select the right input, the selection signal for the active input would always be high and the signal for the inactive input would be low making the active signal to pass through.

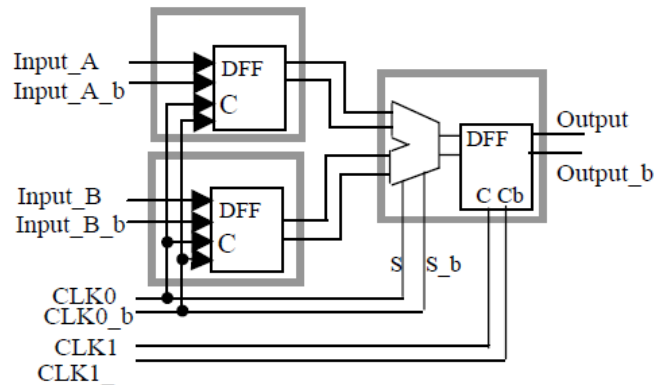


Figure 6.3

Figure 6.4 shows the flowchart diagram of the way values get passed on the configuration circuit.

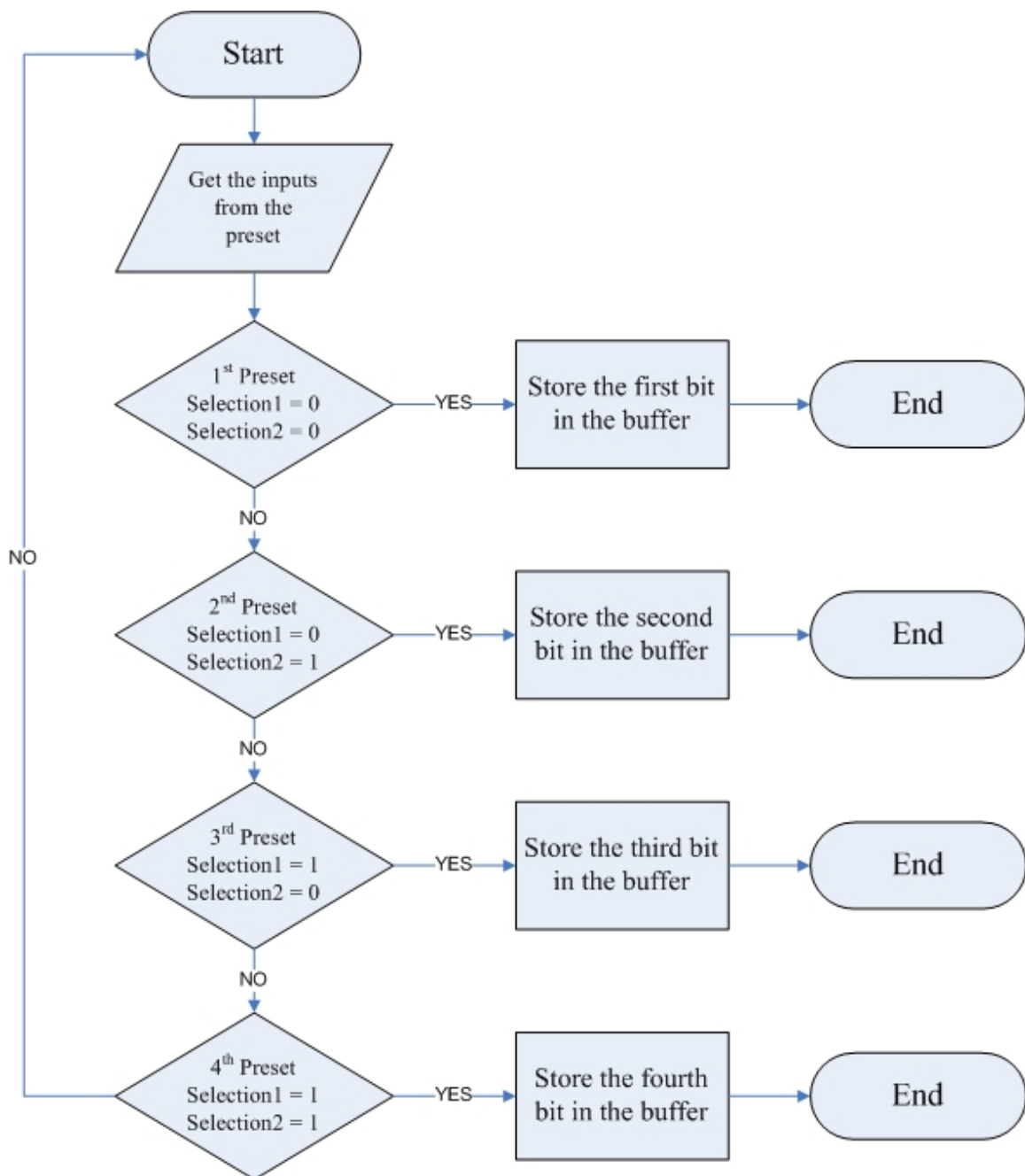


Figure 6.4 – Configuration Circuit Flowchart

7.0 SYSTEM TEST PLAN

7.1 TEST CASE #1

The purpose of this test scenario is to test the functionality of the individual components of our system. This test will be run under normal conditions. We will be testing the following functions:

- 1) Stompboxes are able to send signals when each button is pressed.
- 2) The ADC converters are able to receive the signals from the stompboxes.
- 3) The configuration circuit is able to detect the active signals and pass them through.
- 4) The communication between the configuration circuit and the MAC works properly.
- 5) The MAC is able to combine the signals and delivers the desired output.

7.2 TEST CASE # 2

This case will be used to check if the Multiply/Add Circuit works properly. Since MAC is going to be placed inside the box, we have to make sure if it is able to combine the digital signals in the right way before installing it on the main system. To verify this main functionality, we will be using sound samples (in the format of digital signals), send them to the MAC and will be testing the following conditions

- 1) The MAC is able to detect the right signals
- 2) The MAC is able to pass through a signal if there are no other signals
- 3) The MAC is able to combine a set of signals (up to four)
- 4) The MAC is able to create a digital output out of the combined signals

7.3 TEST CASE # 3

Here we will be testing how the Combinator reacts when the guitar player actually starts playing the electric guitar. For this case, we will have four stompboxes connected to each preset at a time. Then, we will press the button related to each preset, play a single note on the guitar and test if the Combinator is actually combining the signal for the smallest portion of sound.

7.4 TEST CASE # 4

In this case, we will test the functionality of converters and the configuration circuit more specifically. First, we check if the right types of converters are being used on the system and by sending a sample analogue signal to ADC and a digital signal to our DAC and observe if the signals are being converted. Then, we use the converted digital signals and send them through the group of multiplexers on the configuration circuit. We will test if by having each preset pressed, the multiplexers are able to detect the active signals. We will also test if the multiplexers can detect a false signal and reset their operation until they receive the active signals.

8.0 CONCLUSION

This document has discussed the proposed design specifications that meet the functional requirements of the Combinator. Justifications for the chosen components have been discussed as well as a general algorithm for our technology design. Flow charts have been presented to illustrate the process of each component and finally a system test plan was presented to ensure proper functionality of the Combinator. This document provides specific goals for the development and design of the Combinator.

9.0 References

[1] Guo, Jong-Ru, and C. You. The 10GHz 4:1 MUX and 1:4 DEMUX implemented via the Gigahertz SiGe FPGA. Toy, NY. (PDF version of document downloaded March 4th 2010)