# Proposal

Digital Instrument Multi Effects Processing Unit

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## Overview

As technology progresses, the live musicians are no longer satisfied with the original sound their instruments make; they seek ways to modify how they sound through effects pedals, where the sound signals are processed in certain ways that fit the music and make them sound unique.

The 1940s saw the first standalone guitar effects unit from DeArmond. The unit is capable of producing tremolo effects by passing guitar signals through a water-based electrolytic fluid[1]. Then several effect pedals such as delay, echo, fuzz and distortion emerged. Those pedals were driven by purely analog transistor circuits.

In the 1980s, a rise of digitized rack mount effects units occurred. Instead of standalone stompboxes, the digitized counterparts were capable of producing multiple effects in one box and storing presets for quick loading.

Nowadays, the multi-effects processing units have gone through significant improvements in sound quality, delay, size and looks. A typical multi-effects pedal contains the following functions:

1) Amplifier and cabinet simulation, seeking to simulate those iconic sounds of tube amplifiers
2) Distortion effects, including overdrive, distortion and fuzz
3) Modulation effects, including chorus, flanger and phaser
4) Dynamic effects, including booster, compressor and noise gate
5) Equalizer effects
6) Delay and reverb effects

Apart from sound effects, some processors also have built-in loopers and drum machines, adding flexibility to the music performance.

## Implementation

### Hardware

The FPGA will be responsible for processing the instrument signal. For a signal straight out of a guitar, an analog signal buffer and an ADC is required.

The effects are generally divided into two types: linear and nonlinear effects. The linear effects (cabinet IR, delay, reverb, EQ, etc.) can be implemented with a FIR or IIR filter. The nonlinear effects (distortion, modulation, dynamics, etc.) require more in-depth analysis and modeling to mimic the analog circuits and obtain the desired effects.

Each effect block should have its own systemverilog module, accepting the signal from the previous module.

The signal should be output from a speaker, which requires a DAC.

## Software

The software will receive user input either from keys on the development board or keyboard for controlling the parameters and on/off states of the effects. Additional visualization functions will be desired.

# Milestones

We plan to start from one basic effect (cabinet IR or equivalent) to test the functionality of the ADC, DAC and buffer. Considering the time limits of this project, the linear effects (equalizer, delay, reverb, boost, etc.) will be first implemented.

For each effect module, the following steps will be required:
1) Matlab simulation of effect algorithms
2) Simulation from behavioral HDL codes
3) On-board tests

Last but not least, the software-hardware co-design is crucial for user interface. We plan to figure out the way to interface those two domains in parallel with the effects design.

# Reference

[1]https://www.sunpower-uk.com/news/a-brief-history-of-guitar-effects-pedals-infographic/