Digital Signal Processing Techniques Used to Model the Ibanez Tube Screamer Guitar Pedal

Rory Walsh[1] and Conor Walsh[2]

Dundalk Institute of Technology

Abstract. This paper aims to provide a basic overview of methods used in replicating analogue distortion units, using the Csound audio programming language. A key focus will be on the TS- 9 Tube Screamer (TS) analog overdrive guitar pedal by Ibanez. Although lacking in the complex theoretical analysis seen in typical digital audio effects papers, it is hoped that enough information is provided for beginners who wish to begin their own journey into the world of digital emulations of hardware devices.

Keywords: Csound, Analogous Distortion, Emulation

1 Introduction

Distortion effects can be traced back to the mid 1960s. For decades they have played an important role in the sound of electric guitars within popular music. Such effects are based on non-linear distortion of the signal path and can be thought of as wave-shaping circuits. Digital imitations of these analog processors have appeared in many different forms. Certain emulations aim to directly copy a particular analog circuit to replicate its exact behaviour [1]. However, the likelihood of exactly replicating the device chosen for this research is quite low considering the complexity of the device itself. This paper merely looks at methods that could potentially be used to emulate the unit using simplified models.

2 Ibanez Tube Screamer

The TS overdrive effects pedal is produced by Ibanez. It is known for its light distortion, similar to the sound produced from overdriven tube amplifiers. The TS pedal differs from other overdrive pedals on the market due to its unique compression of the waveform, resulting in very little loss of the original signal and capable of creating a full sounding blues tone. Unlike many overdrive pedals, the TS generates symmetrical soft clipping of the incoming signal [2]. Other overdrive pedals available on the market, such as the Boss SD-1, contain similar asymmetrical waveform clippings, which in turn result in a tube-like overdrive [3].What the TS actually does is overload the amplifiers preamp circuit with artificial gain. When the preamp gain is turned up on an amplifier, the TS saturates the signal, creating a full, overdriven tone.

Fig. 1. TS-9 Tube Screamer [4]

2.1 Schematic Breakdown

There are various schematics of the TS available online. ElectroSmash provides the most accurate layout, therefore, it will be the primary reference [5]. This analysis is split into three sections: Input/output buffers, the clipping stage and tone/volume stage. A full schematic is provided below in Figure 2.

Along with the symmetric clipping, the TS also provides a unique mid frequency boost. A characteristic associated with the low pass filtering stages of the circuit.

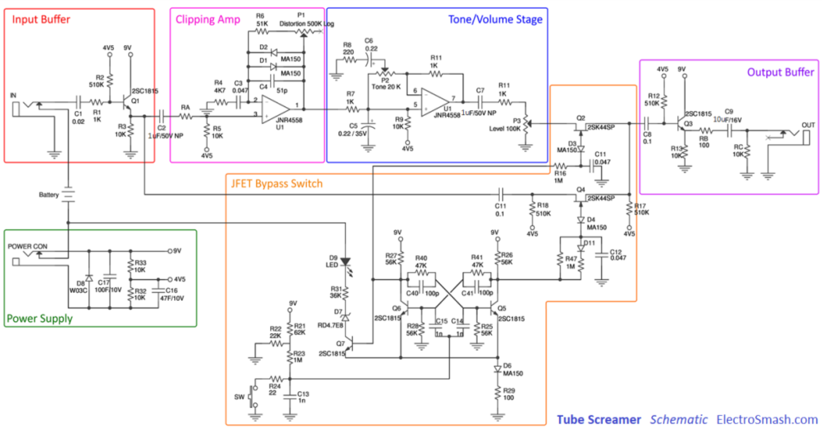

Fig. 2. Tube Screamer schematic [5]

2.2 Csound Implementation

The main features to focus on regarding the TSs unique characteristics are its overdrive and tone controls. Various types of wave-shaping transfer functions were researched during the implementation stages of this research, along with low pass filtering opcodes such as `moogladder`, `butterlp` and `tone`. Ultimately, the use of a `tanh` transfer function [6], along with basic tone controls seemed to be the most suitable combination of processes needed to approximate the sound of the TS.

A simplified implementation using the `tanh` transfer function and `tone` low pass filter opcode has been provided below. This example uses a GEN04 table to analyse the transfer function and create a complimentary normalised table which is used to scale the output.

```
<CsoundSynthesizer>
<CsOptions>
-odac
</CsOptions>
<CsInstruments>
; Initialize the global variables.
sr = 44100
ksmps = 32
nchnls = 1
0dbfs = 1
gifn1 ftgen 1, 0, 4097, "tanh", -180, 180
gifn2 ftgen 2, 0, 1024, 4, 1, 1
instr 1
a1, a2 diskin2 "samples/02_C_Note_DI.wav", 1, 0, 0
;high pass filter all frequencies above 720 mid-hump

aHp butterhp a1, 1220
;low pass all frequencies below mid hump frequency
aLp butterhp a1, 1220
;apply distortion to frequencies above mid-hump only
aDist tablei (aHp+1)/2, gifn1, 1
kScl tablei 1, gifn2, 1
aDist = aDist*kScl
;apply low pass filter to distorted signal
aDist tone aDist, 3090
;sum distorted signal with original low pass filtered signal
aDist = aDist+aLp
outs aDist, aDist
; fout "FinalImp.wav", 4, aDist*.5, aDist*.5
endin
</CsInstruments>
<CsScore>
```

```
;starts instrument 1 and runs it for a 3 seconds
i1 0 3
</CsScore>
</CsoundSynthesizer>
```

The high pass and low pass filters in this code are used to split the signal chain in the same way the TS does. The higher frequencies are passed through the distortion chain, whilst the lower frequencies remain unchanged. Figure 3 displays the similarities between the original TS signal and the Csound emulation. The lower frequencies in the spectrum show a good likeness, whilst the higher frequencies seem to tail off a lot faster in the Csound emulation than the TS. Modifying the filters cut off frequency will help to alleviate this, but it involves a little tweaking.

To gain easier control of the output signal, the final implementation features a set of graphical controls that users can use to tweak aspects of the instruments output. Users can also choose between tanh clipping, or extreme hard clipping. It is possible, with some basic experimentation, to dial in a tone that sounds quite close in timbre to the original TS guitar pedal.

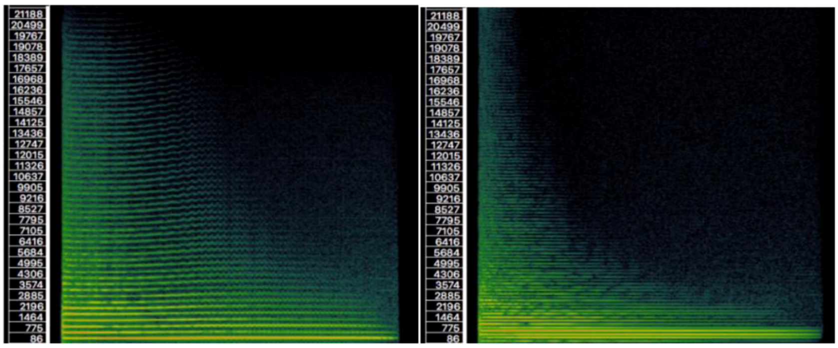

Fig. 3. Spectral analysis of the Tube Screamer (left), *tanh* function and *tone* low pass

3 Conclusion

The focus of this paper is on simple methods that can be used in emulating the output of the Tube Screamer distortion pedal. In many ways it represents quite a naive approach, considering little or no consideration was given to the possibility of aliasing or other complex side-effects of wave-shaping with complex sound sources. Regardless, a combination of a `tanh` transfer function and basic tone controls seem to work quite well as basic tools for emulating the Tube

Screamer. This can be largely attributed to the symmetric form of clipping they produce.

The use of analog electronic circuit simulators such as the SPICE programme [7] were investigated early on during this research. While the ability to emulate schematic circuity provides an interesting pedagogic insight, a full exploration of this tool was far beyond the scope of this research.

The combination of ctcsound [8] and Scipy [9] also proved to be very useful in the explorations of both the original and emulated signals. The ability to forensically plot pressure and frequency graphs proved invaluable. That being said, it is important to keep in mind that the human ear also plays an significant role in DSP emulation, and is summed up nicely by George Massenburg, who states that A DSP engineer with very good ears generally does better than the guy staring at MATLAB emulations. [10]

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