

Digital Audio Systems

DESC9115

Final Written Review

Adam Sirianni

1. Problem Description

One of the most common musical effects present in a wide range of music genres is vibrato. Vibrato is defined as a regular fluctuation of the pitch of a tone. This effect is most commonly utilised in vocals and stringed instruments where the effect is produced by a repeated up and down motion upon the vibrating string, or through fluctuations of the vocal chords. The desire for the use of vibrato is to color and timbre to the overall tone of the instrument generating greater interest in the performance. Due to its prevalence in music, an accurate digital representation can be a valuable tool in many different facets of the industry, from the musician to implementation in post-production audio to even an educational tool for the development of high quality musicians.

The precision of the digital realm allows for the design of 'ideal' naturally occurring musical effects. This however does not equate to the perfect representation of how these effects occur as the human element required when manipulating the fundamental sound can never be

replicated perfectly every time. For vibrato on a stringed instrument this refers to both the Rate (speed at which the position of the string is shifted) and the Depth (frequency shift from the fundamental tone). Through the construction of this digital vibrato producing a more natural sounding vibrato is achieved. One such way this can be achieved is through the use of fractal generators as the modulator of the Low Frequency Oscillator. This product does not deal with the amplitude modulation that occurs along with the frequency modulation when performing vibrato physically.

2. Specification

Zölzer in the DAFx textbook defines vibrato as a periodically varying time delay producing a periodic shift in the pitch. Digital implantation of vibrato must therefore be achieved through the implementation of Delay Modulation. To generate the periodic fluctuations characteristic of vibrato a Delay line is placed on the input signal path, with this delay determining the depth of the frequency shift, driven by a Low

Frequency Oscillator (LFO) to control the rate of the fluctuations. Mathematical definition of vibrato can be extrapolated from *Figure 1* and is displayed below;

$$y(n) = x(n - Z^{-M})$$

where $y(n)$ is the output signal produced by the input signal $x(n)$ delayed by the variable delay Z^{-M} , which is controlled by the Low Frequency Oscillator. Z^{-M} is derived as the variable delay time given as T over the sampling frequency f_s .

$$Z^{-M} = T/f_s$$

This method can be looked at as a Finite Impulse Response Filter (FIR Filter). To create a digital vibrato, there is no 'feed-forward' signal applied in the signal chain, resulting in the output signal of the system being only the delayed input signal. Including a 'feed-forward' signal in the chain results in the production of 2 other effects, Flange and Chorus as the unaffected original input tone is summed with the delayed input signal at the output. Simple adjustments to the code in the form of the addition of this 'feed forward' signal will allow for these effects to be produced in a basic form.

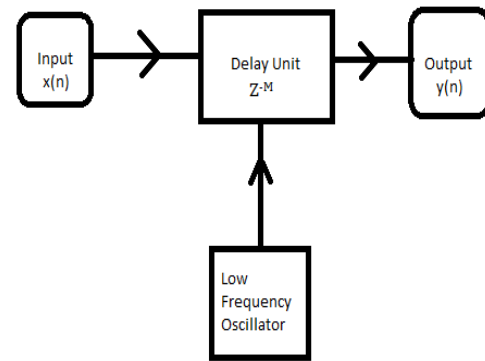


Figure 1 – Basic Digital signal chain producing vibrato effect. Where $x(n)$ is the input signal, Z^{-M} is the rate of delay caused by the Low Frequency Oscillator (LFO) and $y(n)$ is the output signal.

Development of this product is founded in the work done by Udo Zölzer, through the implementation of the Vibrato MATLAB Code shown below, provided in the Digital Audio Effects Text Book (2002).

Martens, Taylor and Miranda (2012) provide additions to the original code including the implementation of the fractal generator and the 2nd order filtering, from their work in the development of a spatial chorus effect unit. (2012). The desire for the addition of a fractal generator for the delay modulation signal originates from the current findings that fractal modulation produces a smoother more 'natural sounding' result. (Martens et. al, 2012). When

replicating a natural musical effect digitally is it desirable to achieve the most similar natural sound possible. Operationally this is achieved through generating the basic fractal number sequences the MATLAB function “frand.64” which is then processed through a low pass filter “M_fq2coef” to get the sub-audio signal to be used by the delay unit. 2 further input parameters are added to the vibrato function to incorporate the variable fractal modulation parameters;

- ModFilterQ = 2nd order Modulation filter bandwidth (Hz)
- MofFilterF = Modulation Filter frequency (Hz)

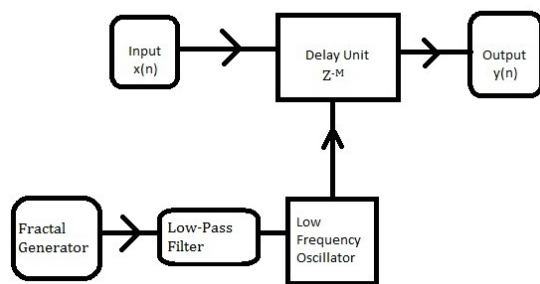


Figure 2 – Digital signal chain for vibrato with the addition of the fractal modulation stage

3. Implementation

[out] =vibrato(Input, SAMPLERATE, Modfreq, Width);

- Input = input signal
- SAMPLERATE = sampling frequency of input signal
- Modfreq = modulation frequency controlled by the Low Frequency Oscillator (LFO) (Hz)
- Width = Delay of input signal (seconds)

Through the design of this model an option will be given to the user to determine which method of vibrato is their preference dependant on their application. Due to the parameters ‘Width’ and ‘Modfreq’ remaining in the function, simple adjustments to the code can be made by simply re-assigning ‘MODFREQ’ to be used as the modulator rather than the fractal sequence by placing a % in front of the line; MOD = resample_noise(n)

And removing the % from the 2 code lines above as shown below;

```
%M=MODFREQ;
%MOD=sin(M*2*pi*n);
MOD = resampled_noise(n);
```

4. Evaluation

To better understand the effect in which the use of fractals has on the

produced vibrato comparisons must be made to a naturally produced physical vibrato on a violin. This physical vibrato can be found through attached file 'V1_02-1.wav'. To produce the digital vibrato using the developed function the parameter settings documented below in the 'appendices' section were used. The MATLAB script 'vibrato_frac_proto2' attached will allow users to process any audio signal desired, with the attached file 'Vibrato_fractal.wav' demonstrating the output signal of the system when a natural violin tone is used as the input signal. Audibly this can be interpreted through the 'rounding off' of the pitch modulation, which is a more natural sound as opposed to the rigid precision of the basic vibrato function. Though subtle the fractal modulation does improve the digital replication as a result of the smoothing to the effect, which previous studies have confirmed. I feel this product has the potential to be an extremely practical and versatile tool in all aspects of the music industry with further development available to broaden its availability.

5. Performance Assessment

In order to quantify the statements made in this report, human assessment of the quality of the vibrato produced by these digital processors provide the necessary, unbiased information. One method in which to gather the required data is through an adapted forced choice procedure. Forced Choice procedures work through the presentation of 2 sound signals at a integer interval with the listener given a directive to indicate a desired criteria, for example loudness. Manipulating this method to sound the naturally produced physical vibrato first, followed by the original Digital Audio Effects produced vibrato and the further developed vibrato code presented in this report, in a randomly selected order. The listener is then asked to identify the signal that best matches the physical vibrato. In order to get useable result this process is repeated numerous times with the order in which the digitally produced vibrato's always randomly changing so that the participant cannot identify a pattern, which

would ultimately contaminate the results given.

Acknowledgements:

I acknowledge the use of MATLAB scripts and function developed by Martens, W. Taylor, R. Miranda, L and Zölzer, U as being utilized in this developed function.

References:

U. Zölzer, (2002) DAFx. *Digital Audio Effects*. John Wiley & Sons.

Taylor, R. (2012) *Spatial Chorus with*

Fractal Modulation, The University Of Sydney

Martens, W. Taylor, R. Miranda, L. (2012) *Spatial Chorus Effects Processor*, Online Website

Martens, W. Taylor, R. Miranda, L, (2012) *Predicting the fluctuation strength of the output of a spatial chorus effects processor*, Audio Engineering Convention 133.

G. Evangelista. (2006) *Fractal modulation effects*. 9th Int. Conference on Digital Audio Effects, Montreal, Canada

Appendices

MATLAB Function Parameters

```
Modfreq = 5.; % Function Parameter Setting
Width = 0.0006; % Function Parameter Setting
ModFilterF = 5; % Function Parameter Setting
ModFilterQ = 10; % Function Parameter Setting
Input %Signal to be processed
SAMPLERATE %Sample rate of input signal
```