ZynAddSubFX
an open-source software synthesizer

written by Nasca Octavian Paul

zynaddsubfx@yahoo.com

http://zynaddsubfx.sourceforge.net

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Features:

- Realtime, poliphonic, multitimbral and microtonal
- 3 powerful synth engines
- Many types of effects
- Full control of a large number of parameters

- The instruments generated by it has very high quality and “warmth”
- Everything is generated by the synth (eg. no external samples)
- Easy to use user interface
- Many others...
ZynAddSubFX Structure

• It is divided into several (music) parts.
• Midi channels can be assigned to parts
• The effects can be connected as System Effects, Insertion Effects or Part Effect
ZynAddSubFX Main Structure

Part 1
- 1 note
- Insertion effect
- Insertion effect

Part 2
- 1 note
- Insertion effect
- Insertion effect

System effect 1
- Insertion effect
- Insertion effect

System effect 2
- Insertion effect

Other Parts

Components
- Volume change
- Mixer

Other system effects
Part's structure

- One part contains a single instrument or an instrument kit
- Each part has its own effects
- Each instrument's kit item has 3 synth engines: ADsynth, SUBsynth and PADsynth
Synth engines

• **ADDsynth** – is a highly complex synthesis engine that has several oscillators that can generate any waveform. This engine has filters, LFOs, envelopes, resonances and supports FM, PM, RingModulation synthesis.

• **SUBsynth** – is a simpler synth that generates the sound by filtering the desired harmonics from white noise.

• **PADsynth** – is a new synthesis method which will be described later.
Diagram for ZynAddSubFX synth engines
ADDsynth

- This engine is divided into several voices.
- Each voices has own oscillator, filter, envelopes and LFO's. The envelopes and LFO's controls the amplitude, frequency and the filter's frequency.
- For each voice there is an extra oscillator which is used as a modulator.
- Stacked FM possible
SUBsynth

• The SUBsynth generates a white noise which is filtered by band-pass filters
• This engine has amplitude, bandwidth and frequency envelopes and a filter
• Each harmonic has it's own bandwidth control
PADsynth
(Paul's ADditive synth)

- This is the most innovative sound engine. It uses the idea that every harmonics is not a single “sine” frequency, but is a frequency band.
- It generates wavetables by doing IFFT's of a very long arrays. The sound is generated by playing these wavetables at different speeds. For one instrument there are more wavetables.
PADsynth synthesis steps

Frequency distribution of a single harmonic

Frequency components (a LARGE array, eg. 256K samples)

Amplitude

Convert to complex numbers and randomize the phases

IFFT

It results a long sample (few seconds) which loops perfectly.
Effects Types

- ZynAddSubFX supports 8 types of effects
  - Reverberation
  - Echo
  - Chorus/Flange
  - Phaser
  - AlienWah
  - Distortion
  - EQ
  - Dynamic filter (eg. Vocal Morpher, WahWah, etc.)

- The effects has many parameters
Basic Blocks of ZynAddSubFX

- Oscillators – are used by ADDsynth and PADsynth
- LFO's – low frequency oscillators
- Envelopes
- Filters
Oscillators

- They generate the sounds by processing some base-functions. There are many ways to make the desired harmonic structure.
- They can generate any waveform
- Offers a lot of advanced features like adaptive-harmonics, phase/amplitude randomness, etc.
LFO

• ZynAddSubFX has many LFO types
• They changes the amplitude, frequency of the signal or frequency of the filters
• LFO parameters are:
  – Basic parameters: frequency, amplitude, delay
  – Advanced paramters: type, frequency stretch, continous-mode, frequency and amplitude randomness.
Envelopes

- Envelopes has 2 modes: parametric (ADSR, ASR, etc.) or free
  - Parametric mode offers easy access to Attack, Decay, Sustain or Release parameters
  - Free mode means that the envelope can have any shape
Filters

• Filter types
  – Analog Filters (low-pass, high-pass, band-pass, notch, peak, and shelf filters)
  – Arbitrary format filters
    • They can be used, for example, to make vowels
  – State variable filters

• There is a special kind of filters: the resonances (used by oscillators). These has an arbitrary frequency response.
ZynAddSubFX design principles

- To be sure that this synthesizer can produce beautiful sounds, several principles was used by the author
  - Bandwidth of every harmonic
  - Randomness
  - Amplitude decrease of higher harmonics on lower velocities
  - Resonance
The bandwidth of each harmonic

- This considers the harmonics as frequency bands. Also, instead of considering the time-domain changes of the sounds, is much simpler to consider only frequency-domain parameters of these harmonics (frequency spread and phases).

- Even if is well-known the fact that the vibratto or detune cause frequency spread, there are interesting facts about the harmonics which are ignored by DSP/music literature.

- Using this idea can result very simple synthesis algorithms which produces very beautiful sounds.

- The base of the ZynAddSubFX synth engines comes directly from this idea.
Narrow harmonic vs wide harmonic

Narrow

Wide (½ semitones)

Bandwidth of each harmonic
Important rule #1

- In beautiful sounds, higher harmonics have bigger bandwidths
Important rule #2

- In beautiful sounds, phases of sine components of the harmonics are random
- This happens, usually, in ensembles and choirs
- The reverberation randomizes the phases of the sine components of the harmonics
PADsynth and meaning of the “Harmonic Profile”

Zoom In

Bandwidth of each harmonic
Randomness

- Digital synthesis sounds “cold” because the same recorded sample is played over and over at each keypress.

- To make sound “warm”, ZynAddSubFX has many parameters that adds randomness.

Few keystrokes at the same pitch/strength with same instrument.
Resonance

- ZynAddSubFX offers many ways to make resonance: by using filters (formant or resonance), adaptive-harmonics, etc.
Adaptive harmonics

• It is a simple, but very effective way to produce natural-like sounds (e.g. A listener cannot realize that the sounds comes from a synthesizer and s/he thinks that is produced by real (natural) instrument)

The Spectrum data is resampled according to the division between a fixed base frequency and the note's frequency.
Microtonal

- The most western music is tuned in the Equal Temperate scale with 12 notes/octave
- ZynAddSubFX supports any tuning with any number of notes/octave
- It can import tunnings in Scala formats and keyboard mappings
Todo list

• Manual and documentation
• Add the possibility to export instruments as wav (or sfz)
• On the long term:
  – Realtime-safe
  – Solve VST issues
  – Other synthesis engines
Audio Demos

- Play many instruments as possible
- JACK demo
Questions