HELSINKI INSTITUTE FOR INFORMATION TECHNOLOGY

Audio Synthesis by
Bitwise Logical Modulation

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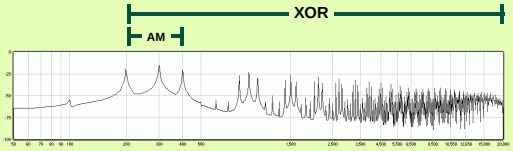
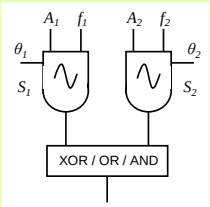
Rich spectra from two sinusoids

The synthesis of rich audio spectrum requires usually complex source waveforms, a large number of simple source components, or increased algorithmic complexity. This work describes an implementation in which elementary bitwise logical operations (XOR, OR, AND) are applied to two sinusoidal oscillators, in order to produce dense and harmonic sonic material. The synthesis method is computationally efficient and easy to control, but it is not generally band-limited.





1. Introduction

Algorithm:

- convert oscillator outputs to integers
- perform XOR, OR or AND operation
- convert result back into floating point format

A	B	OR	AND	XOR
0	0	0	0	0
0	1	1	0	1
1	0	1	0	1
1	1	1	1	0

Properties:

- amplitude is bounded to max(S_1, S_2)
- sharp edges due to carryless operation (local overflows)
- XOR is zero when all synthesis parameters are equal
- XOR has an octave shift (rule of signs is different from that of OR and AND)
- XOR does not have a carrier peak in spectrum

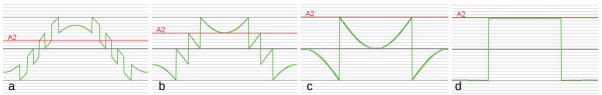
Two implementations:

- PD patch with custom externals (C)
- VSTi plugin (.net and C#)
- source code available

2. Synthesis Parameters

Independent amplitude, phase and frequency parameters for each oscillator.

A) Amplitudes determine waveshape decoration



A_2 = 25 | A_2 = 50 | A_2 = 100 | A_2 = 100, A_1 = 1

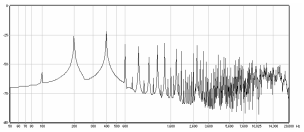
- Carrier sine wave decorated with stepwise segments of height A_2 (a-c)
- A_1 defines segment curvature (a-c: A_1=100, d: A_1=1)
- Sharp corners produce aliasing

B) Phase difference mirrors waveshape and flips polarity

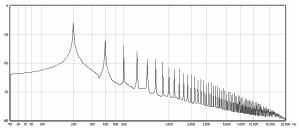
0 | π/2 | π | 3π/2

- Full polarity flip at π
- From subtle to dramatic effect (depends on other parameters)

C) Frequencies define sideband spread



high modulation amount (A_2 = 50)

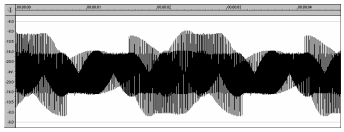


low modulation amount (A_2 = 1)

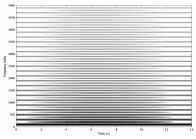
- Sidebands at $f_1 \pm k\, f_2$ (k=1,2,3,...)
- Negative frequencies mirrored at 0 Hz
- Steady states when f_1/f_2 is a rational number
- Almost band-limited spectra with small modulation amounts
  - e.g., $f_1 = f_2$ produces a sawtooth wave when A_2 = 1
- Unipolar carrier:
  - peaks at $f_1 \pm k\, f_2$ (k=1,3,5,...)
  - less prominent at $f_1 \pm k\, f_2$ (k=2,4,6,...)

3. Animation Examples

- Oscillator detuning (< 20 cents) produces thick and evolving timbres
- Added AM or FM produces even thicker timbres
- Smooth morphing between square - sawtooth - square
- Rhythmic effects with control rate modulation



detuned and amplitude modulated waveform



square - sawtooth - square morph

4. Conclusion

Possible application: rich source material for further processing

- e.g., for thick supersaw, polysynth, bass and lead sounds

Benefits:

- can produce simple and complex harmonic waveforms
- easy to control
- efficient to compute

Disadvantages:

- aliasing, band-limited only with small modulation amounts
- lack of generality

HIIT is a joint research institution of Helsinki University of Technology (TKK) and the University of Helsinki (UH).