

21M.380 MUSIC AND TECHNOLOGY
SOUND DESIGN

SECOND QUIZ (QZ2)
SOUND SYNTHESIS TECHNIQUES

MONDAY, MAY 2, 2016
35 MINUTES, 10% OF TOTAL GRADE

1 Distinguishing synthesis techniques and their applications

1.1 Identify synthesis technique by ear (15%)

You will hear a sound example.

- Which synthesis technique might have been used to generate this example? Select a single answer and note that all synthesis parameters remained unchanged throughout the entire example.

- Additive synthesis Subtractive synthesis
 Waveshaping Wavetable synthesis
 Amplitude modulation Frequency modulation
 Granular synthesis

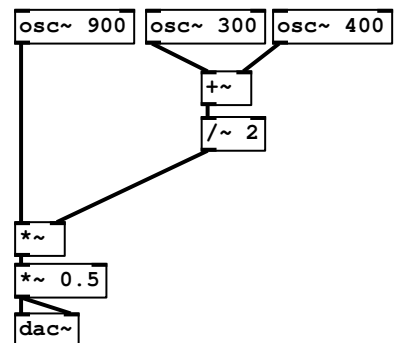
- What brings you to this conclusion?

Spectrum becomes brighter as the input amplitude increases, which indicates a non-linear technique, specifically a waveshaping function that is linear for low input amplitudes, but gently clips the output for higher input amplitudes, generating harmonic distortion.

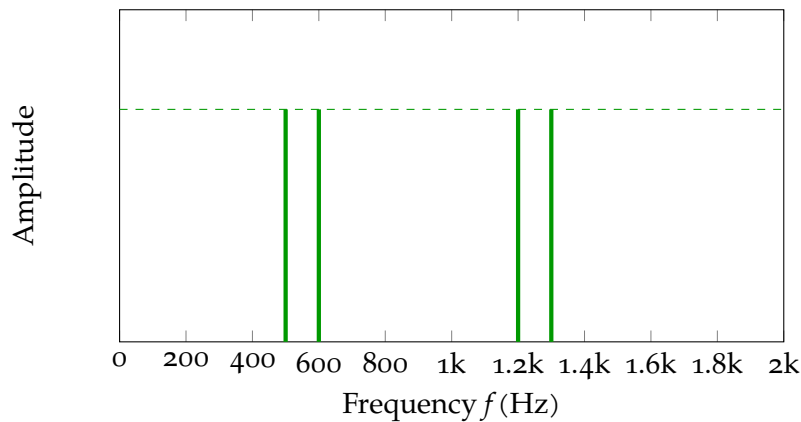
1.2 Pd patch analysis (15%)

- Which synthesis technique does the Pd patch on the right implement? Select a single answer.

- Additive synthesis Subtractive synthesis
 Waveshaping Wavetable synthesis
 Amplitude modulation Frequency modulation
 Granular synthesis



- Annotate the Pd patch on page 1 with comments that indicate what brings you to this conclusion. Label the [osc~] objects to clarify their respective role and impact on the resulting sound. What is the purpose of the [/~ 2] and [*~ 0.5] objects?
- Draw the spectrum generated by the patch on page 1. Indicate the precise frequencies of all partials, as well as their amplitude relationships.



1.3 Which technique for which sound? (10%)

Imagine you have to synthesize the following sounds. Check all synthesis techniques that you would consider for each task. You can select multiple techniques for each sound. Rationalize your selection in a few keywords.

1. Wind chimes

- | | |
|--|--|
| <input checked="" type="checkbox"/> Additive | <input type="checkbox"/> Subtractive |
| <input type="checkbox"/> Waveshaping | <input type="checkbox"/> Wavetable |
| <input type="checkbox"/> AM | <input checked="" type="checkbox"/> FM |
| <input checked="" type="checkbox"/> Granular | |

Rationale: Pitched yet inharmonic: Add./FM. Texture: granular

2. Raindrops

- | | |
|--|---|
| <input type="checkbox"/> Additive | <input checked="" type="checkbox"/> Subtractive |
| <input type="checkbox"/> Waveshaping | <input type="checkbox"/> Wavetable |
| <input type="checkbox"/> AM | <input type="checkbox"/> FM |
| <input checked="" type="checkbox"/> Granular | |

Rationale: Droplets: filtered noise. Stochastic process: granular

3. **Hot charcoal**

- | | |
|--|---|
| <input type="checkbox"/> Additive | <input checked="" type="checkbox"/> Subtractive |
| <input type="checkbox"/> Waveshaping | <input type="checkbox"/> Wavetable |
| <input type="checkbox"/> AM | <input type="checkbox"/> FM |
| <input checked="" type="checkbox"/> Granular | |

Rationale: Hot coal: filtered noise. Stochastic process: granular

4. **Violin**

- | | |
|---|--|
| <input type="checkbox"/> Additive | <input type="checkbox"/> Subtractive |
| <input checked="" type="checkbox"/> Waveshaping | <input type="checkbox"/> Wavetable |
| <input type="checkbox"/> AM | <input checked="" type="checkbox"/> FM |
| <input type="checkbox"/> Granular | |

Rationale: Louder violin tones have more harmonics → nonlinear

5. **Blown bottle**

- | | |
|--------------------------------------|---|
| <input type="checkbox"/> Additive | <input checked="" type="checkbox"/> Subtractive |
| <input type="checkbox"/> Waveshaping | <input type="checkbox"/> Wavetable |
| <input type="checkbox"/> AM | <input type="checkbox"/> FM |
| <input type="checkbox"/> Granular | |

Rationale: Airy, yet pitched sound suggests filtered-noise approach

2 Additive synthesis

2.1 Check all statements that are true (10%)

False positives will be penalized.

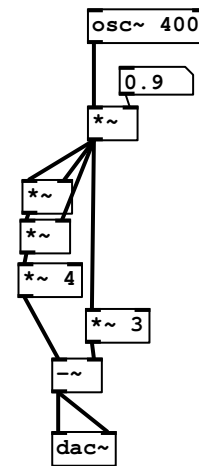
- A bandlimited sawtooth oscillator can be implemented by means of additive synthesis, where one period of the resulting waveform is typically stored in a table.
- When synthesizing a resonating bell by means of additive synthesis, the phases of all partials must be synchronized.
- When synthesizing a vibrating string by means of additive synthesis, the phases of all harmonics should be synchronized.
- The large amount of control data is one of the main challenges associated with additive synthesis.
- In additive synthesis, so-called *sidebands* are generated by multiplying signals of different frequencies with each other.

3 Waveshaping and wavetable synthesis

3.1 Chebyshev polynomials (10%)

- The Pd patch on the right implements the Chebyshev polynomial $T_3 = 4x^3 - 3x$. Which frequencies can possibly appear at the [dac~], assuming the number box currently set to 0.9 stays within the range between 0.0 and +1.0? Select only a single answer.

- 400 Hz only
- 800 Hz only
- 1.2 kHz only
- 400 Hz and 800 Hz
- 400 Hz and 1.2 kHz
- 800 Hz and 1.2 kHz
- 400 Hz, 800 Hz, and 1.2 kHz



- Argue in favor of your selection:

Odd Chebyshev polynomials T_n (where $n = 1, 3, 5, 7, \dots$) generate odd harmonics up to the n^{th} harmonic (and only the n^{th} harmonic if the input gain is 1.0).

3.2 Wavetable vs. additive synthesis (5%)

- Imagine you want to design a pipe organ software synthesizer with a lot of harmonics for a slow machine with limited CPU (central processing unit), but a generous amount of RAM (random access memory). Considering these hardware restrictions, which of the following two synthesis techniques might be more suitable for the task?

- Additive synthesis
- Wavetable synthesis

- Explain why:

The signals generated by an additive synthesizer need to be computed on the fly, which requires primarily CPU power. Wavetables, on the other hand, are pre-computed, but need to be loaded into RAM to be quickly accessible when needed.

4 Granular synthesis

4.1 Check all statements that are true (10%)

False positives will be penalized.

- When performing extreme time stretching with synchronous granular synthesis, the frequency inherent to the repetition of grains can become audible as an artefact.
- FM synthesis is generally much more computationally expensive than granular synthesis.
- The disadvantage of pitch shifting by means of granular synthesis is that it also changes the duration of the resulting sound.
- Granular synthesis is a technique suitable for the creation of stochastic sound textures.
- The individual grains generated by a granular synthesizer are frequently enveloped using a Gaussian bell curve.

5 AM and FM synthesis

5.1 AM synthesis techniques (10%)

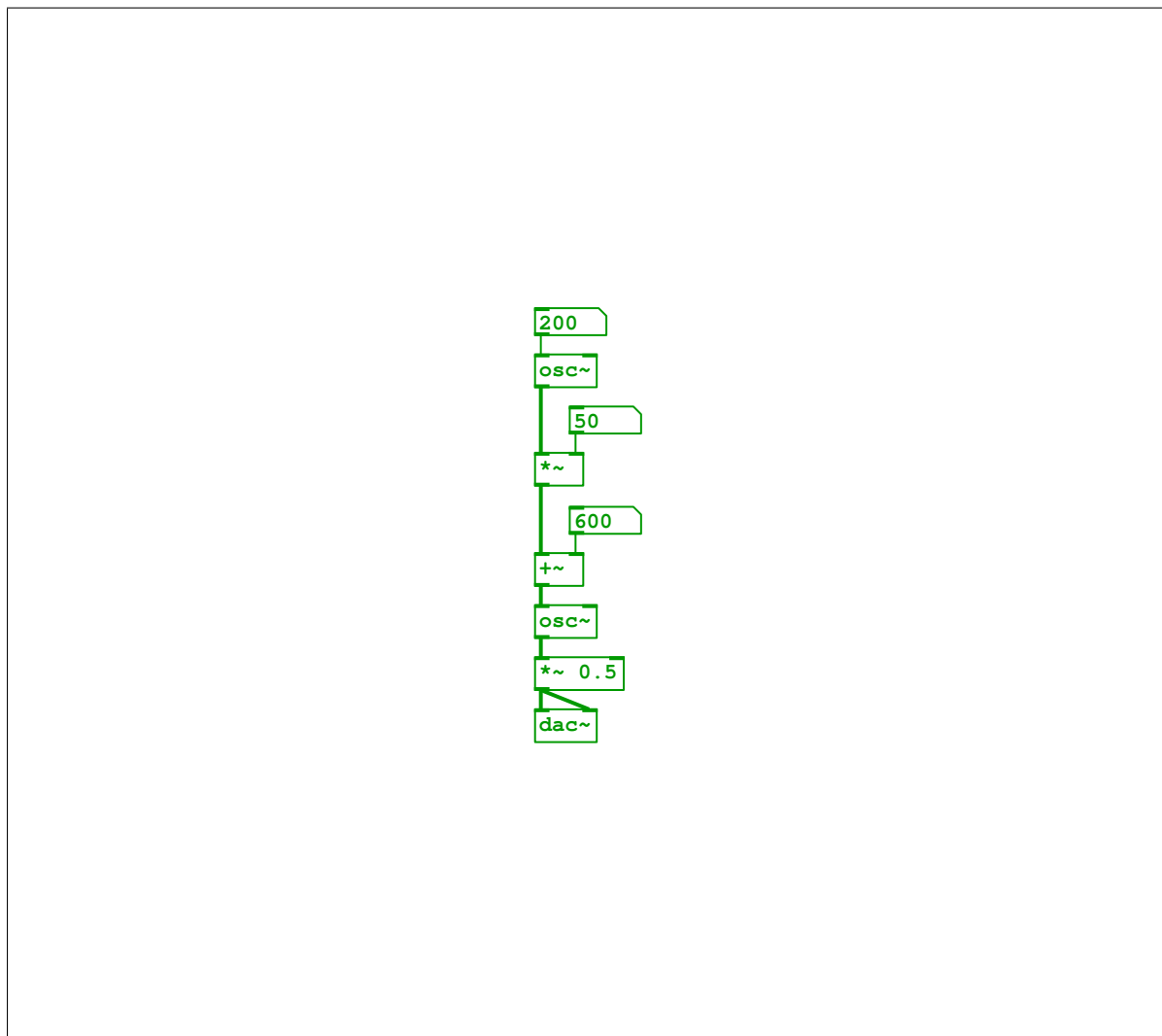
Falls positives will be penalized.

- The original carrier and modulator frequencies are not audible in the output of an *all-band modulator*.
- The difference between basic amplitude modulation (by multiplication of two signals) and a *ring-modulator* is the presence of the original carrier frequency in the output spectrum of the latter.
- The *Hilbert transform* is useful in AM synthesis to generate both, the sum *and* difference of two frequencies.
- Single-sideband modulation* generates only a single frequency, which is given as the product $f_C \cdot f_M$ of carrier and modulator frequency.
- AM synthesis inevitably generates harmonic spectra.

5.2 Create a simple FM synthesizer in Pd (15%)

In the space below, draw a Pd (vanilla) patch that implements a simple, self-contained frequency modulation synthesizer.

- Include three number boxes for the dynamic control of the following parameters:
 - Carrier frequency f_C
 - Modulator frequency f_M
 - Frequency deviation Δf or modulation index i
- Label the three number boxes with comments to clarify which controls which of the above parameters.



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