SOUND

WHAT IS SOUND?

- Waves (vibrations/disturbances) traveling through a medium (air, water, bone)
- Wave types
  - Impulse – single pulse
  - Noise – random wave, ongoing but no repetition
  - Pitched – repeating (oscillating waveform)
  - Sine waves/sinusoidal – simplest, building blocks for more complex sounds

SOUND WAVES

- Amplitude – How compressed the peaks are (distance between them) – related to loudness
- Wavelength (λ) – How far apart the peaks are
- Speed (c) – How fast the peaks move through the medium
  - In air – 343 meters/second, 768 mph, about 5 seconds per mile (at 20°C)
  - In water – 1484 m/s, about 4.32 times faster
  - In bone – 2650 m/s (Why bone?)
- Frequency ($f = c / \lambda$) in Hertz (Hz) (cycles/sec) – related to pitch
- Concert A = 440 Hz (to tune an orchestra)
  - $\lambda = c / f$ = (343 meters/sec) / (440 Hertz) = 0.78 meter
  - f stays put in different mediums => λ changes with c

DIGITAL AUDIO

Capture, storage and retrieval of sound usually happens digitally (these days)

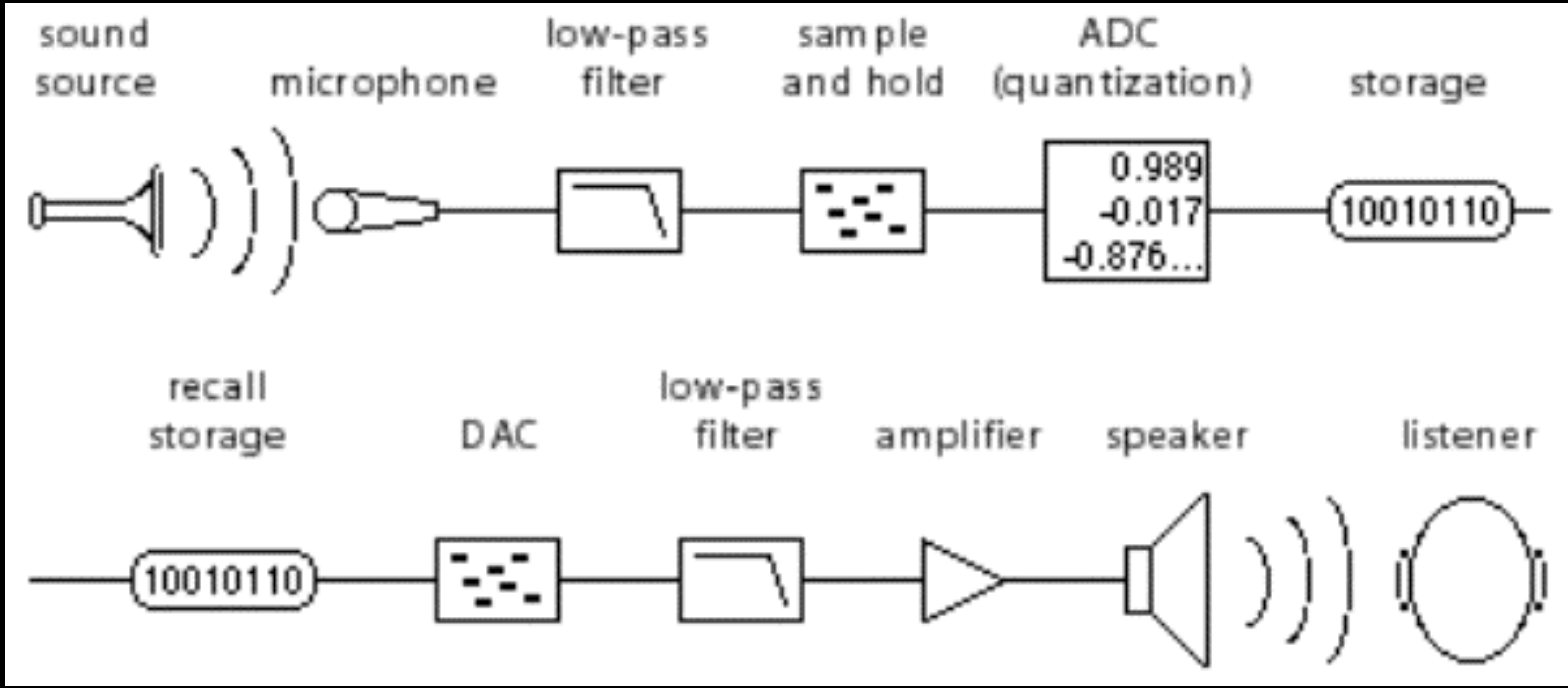
- Digital – Variations in air pressure are converted to voltages then **sampled** at discrete times and stored on tape, disk, flash memory as a sequence of discrete numbers - conversion of a continuous-time signal to a discrete-time signal.

- Mechanical (Analog) – Needles making scratches on moving tinfoil, wax, shellac, vinyl

- Electric (Analog) – Continuous voltage curves stored as magnetic fields on moving wire, cylinder, tape

DIGITAL AUDIO

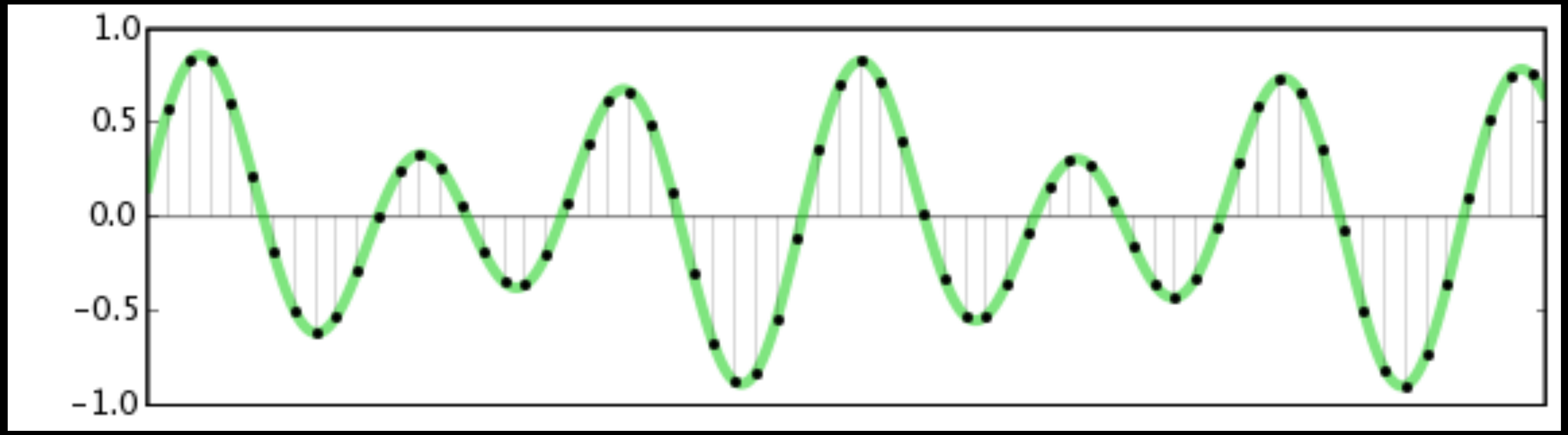
- A2D / D2A



More info: https://docs.cycling74.com/max8/tutorials/02_mspdigitalaudio

DIGITAL AUDIO

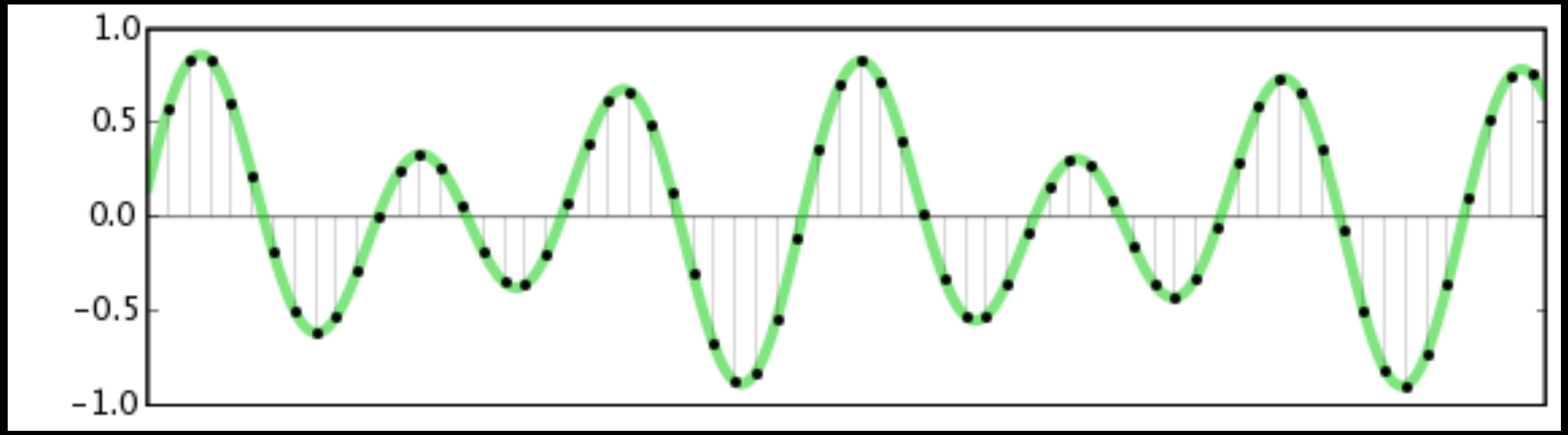
- Sampling:
  - Sampling Rates: how often you are taking “snapshots" of the signals (44.1kHz, 48kHz, 96kHz, etc)



- Bit Depth: number of bits of information in each sample (resolution). 16-bit (CD), 24-bit (DVD/Blu-ray). Affects dynamic range.

DIGITAL AUDIO

- Sampling:
  - An audio sample is simply a small portion of stored sound (e.g. from a file or a data structure like an array) that can accessed, played back and otherwise manipulated.



Processing Sound library uses the SoundFile and AudioSample classes for this

SOUND SYNTHESIS

Sound synthesis is the technique of generating sound “from scratch”, using electronic (analog or digital) hardware or software

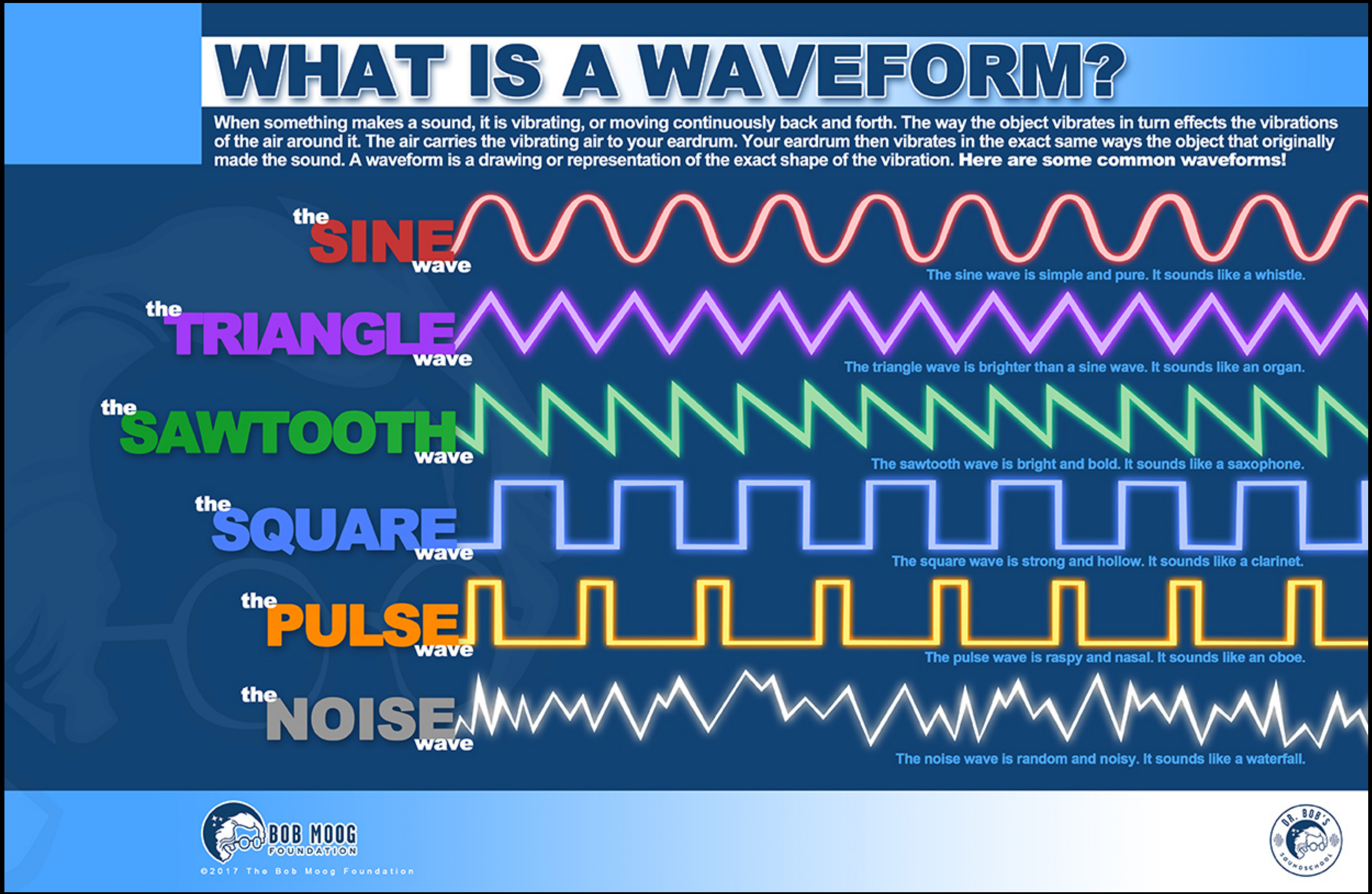
- Many types:
  - Subtractive
  - Additive
  - Granular
  - FM (Frequency Modulation)
  - Wavetable
  - and many more…

SOUND SYNTHESIS

Components of a typical sound synthesis system

- Oscillator/Waveforms
- Envelope generator
- Filter
- LFO (Low frequency oscillator, acts as modulator)
- Amplifier

SOUND SYNTHESIS



Oscillator: generates these repeating or periodic waveforms

Processing & p5.js Sound libraries have classes for generating all of these

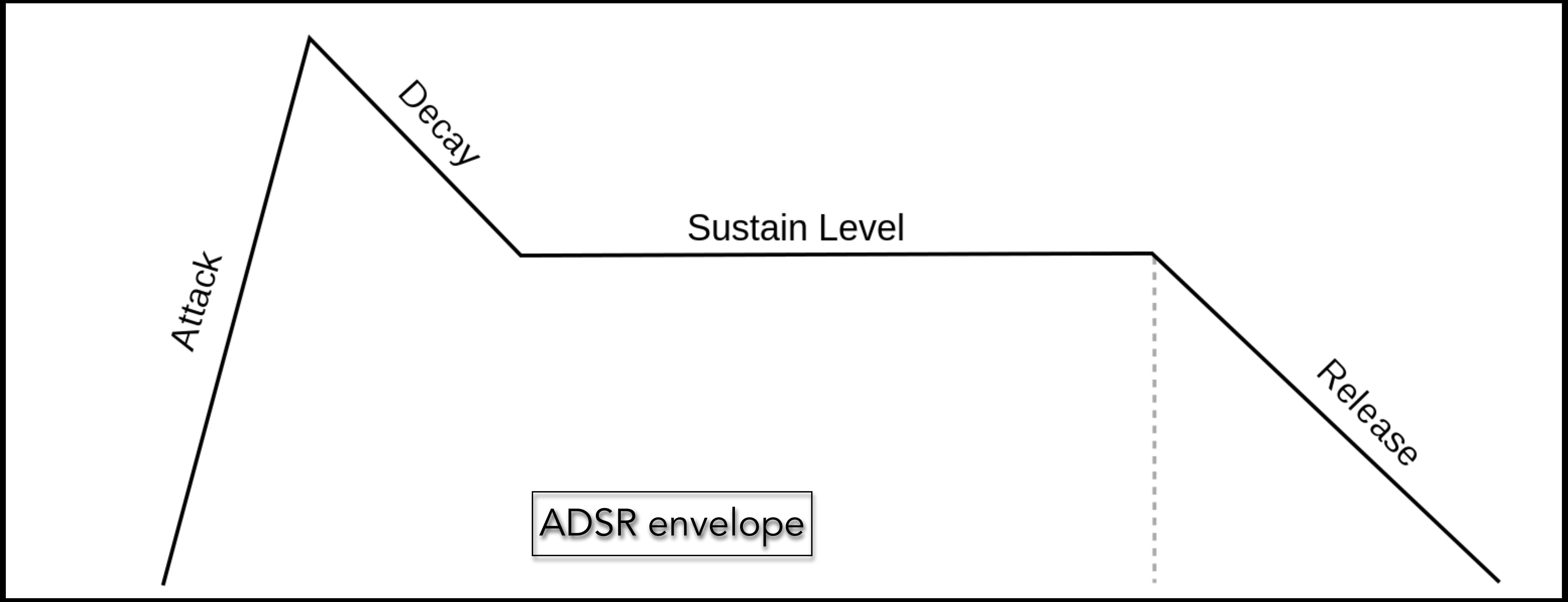
Arduino tone() function produces these only

From https://moogfoundation.org/learning-synthesis/synthesis-fundamentals/

SOUND SYNTHESIS

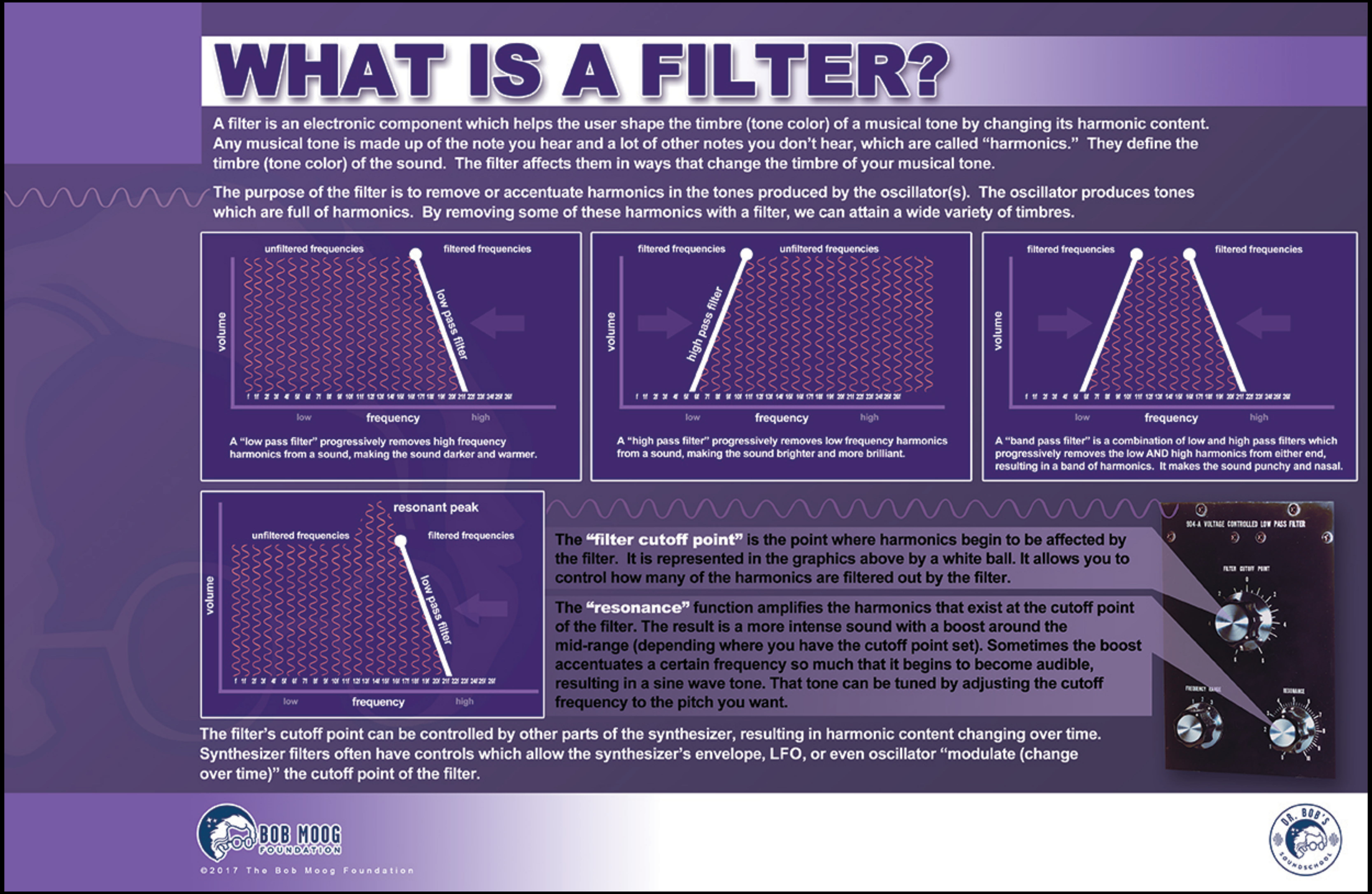
Envelope: control amplitude shape over time.

Can be applied to volume (e.g. of an amplifier, filter cutoff and more)



note: Processing sound library only offers ASR envelope

SOUND SYNTHESIS



From https://moogfoundation.org/learning-synthesis/synthesis-fundamentals/

Filter: shapes timbre (tone color) by altering spectral/harmonic content (typically by removing certain range of frequencies)

Processing and p5.js Sound libraries have classes for lowpass, highpass & bandpass filters

SOUND SYNTHESIS

LFO (Low Frequency Oscillator): repeating waveform of very low pitch (usually below range of human hearing) used to alter the shape or "modulate" the pitch or amplitude of your sound or some other part of your synth.

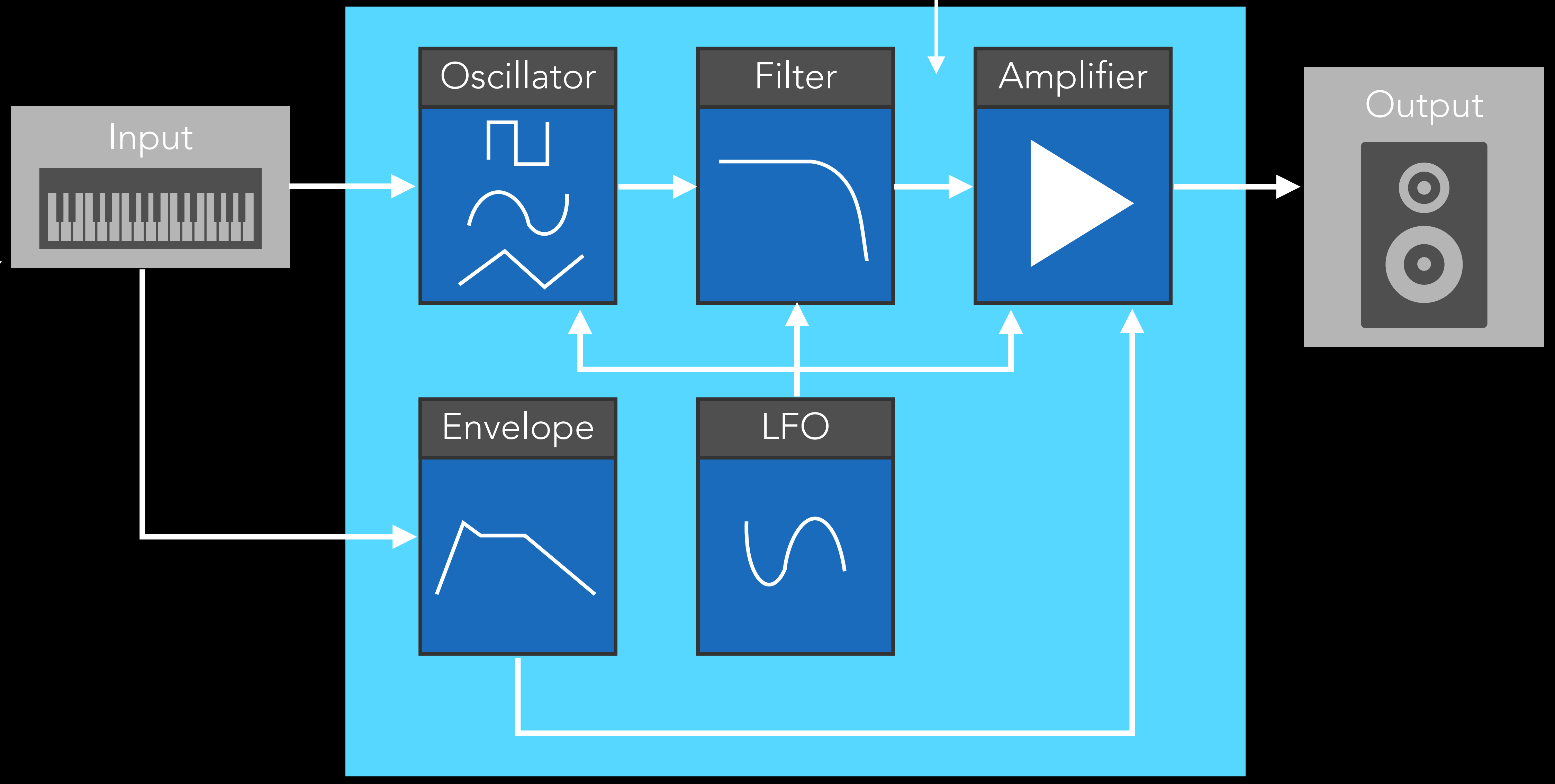
Basically you are using a waveform oscillator not as a sound source but a modulation source

SOUND SYNTHESIS

Amplifier: Volume control

SOUND SYNTHESIS

Effects:
Time-based: (reverb, delay, chorus, etc)
Dynamic: (compressor, expander, noise gate, etc)
Pitch/Harmonic: (harmonizers, pitch-shifters, auto-tune, etc.)

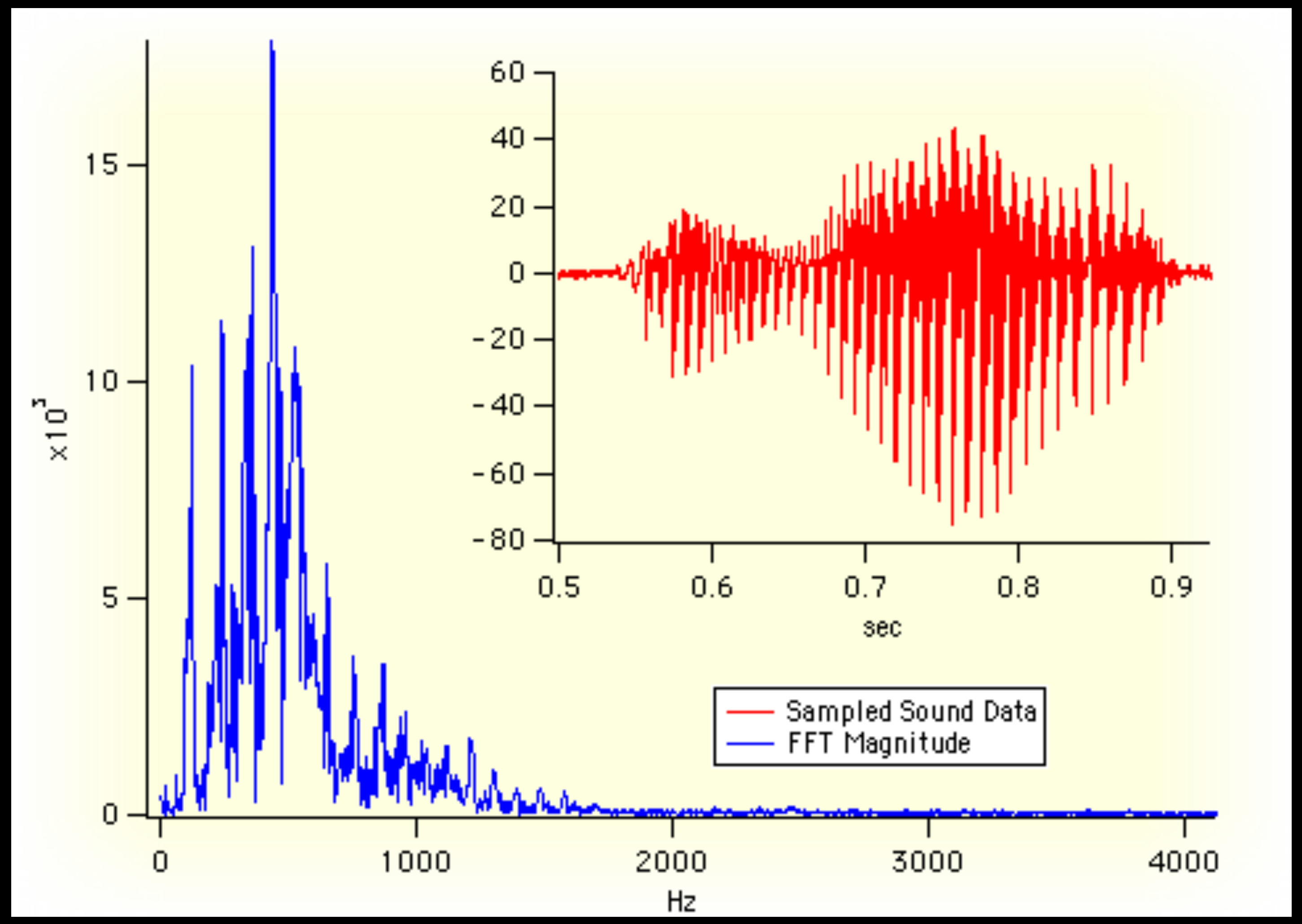


MIDI
Control voltage
Sensors & alternative interfaces
Posenet data
etc…

Typical synthesis set-up

TIME DOMAIN & FREQUENCY DOMAIN

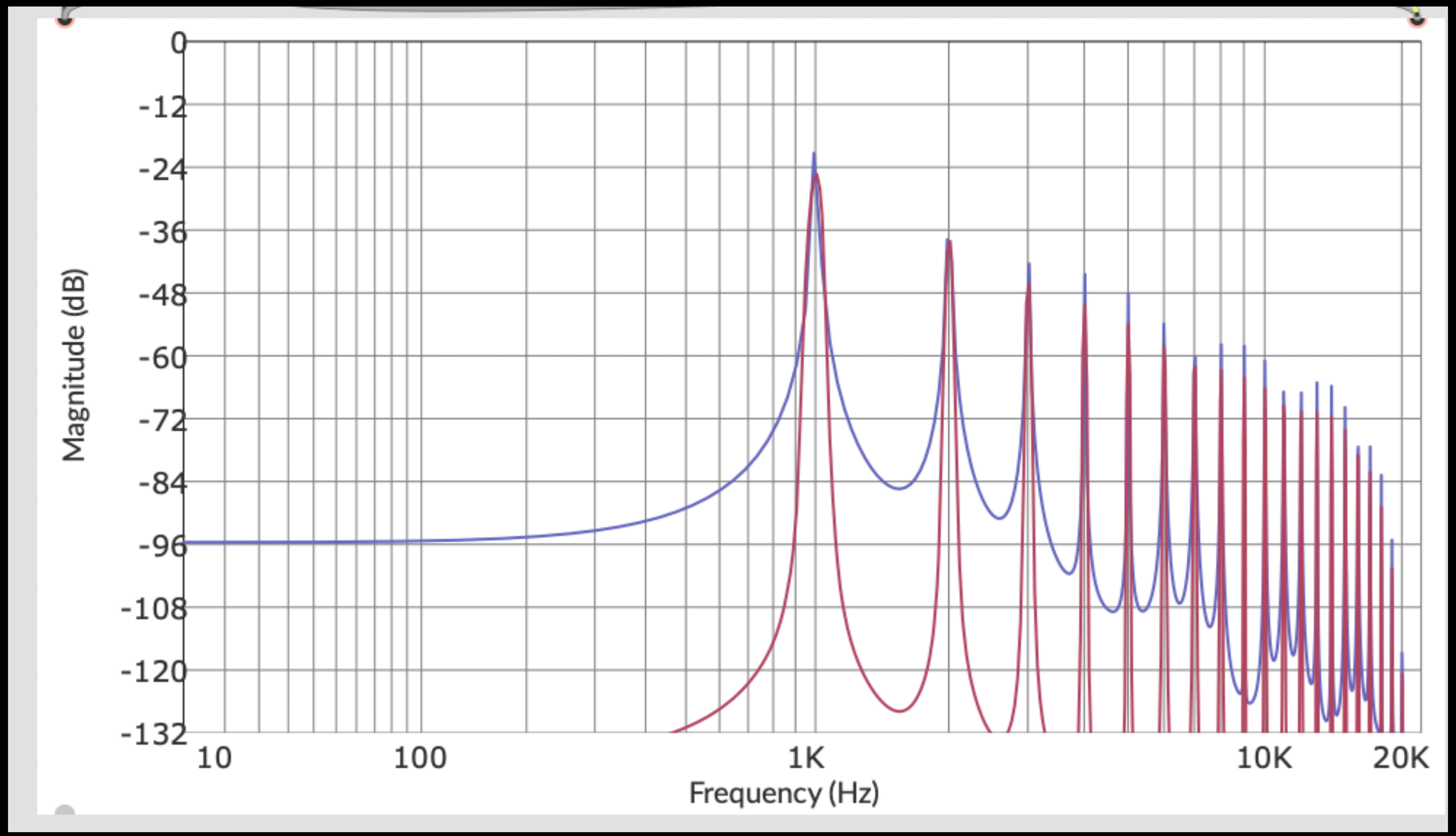
- Waveform: time domain (X axis is time, Y axis is amplitude at that time)
- Spectrum: frequency domain (X axis is frequency, Y is amplitude at that frequency over the course of the segment being analyzed.)



From http://www.wavemetrics.com/products/igorpro/dataanalysis/signalprocessing/fouriertransforms.htm

TIME DOMAIN & FREQUENCY DOMAIN

- Spectrogram is a series of spectra (spectrums) (usually done over time or in real-time)
  - Each spectrum taken on a segment of the waveform
  - Use a sliding window to define the segments
  - Windows usually overlap
  - Windows are enveloped (ramp amplitude up and down)
  - Usually accomplished via FFT (Fast Fourier Transform)



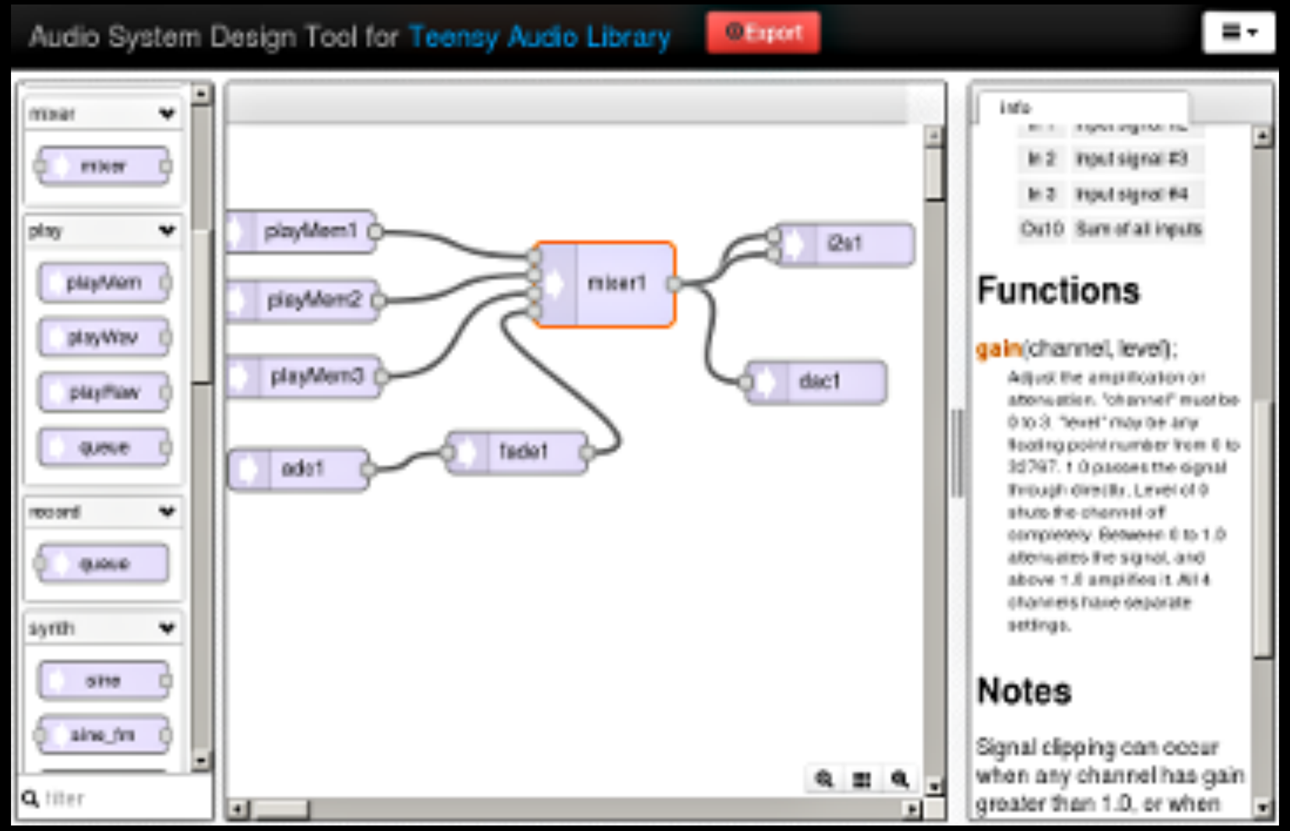
FFT spectrum of a sawtooth wave at 1kHz

SOFTWARE TOOLS FOR SOUND

- Processing Sound Library
- Minim for Processing
- p5.js Sound Library
- openFrameworks addons (too many to list)
- Max
- PD (Pure Data)
- SuperCollider
- FoxDot (Python library and programming abstraction layer for SuperCollider)
- ChucK
- Csound
- Faust
- JUCE

MICROCONTROLLERS FOR SOUND

Teensy Audio Library

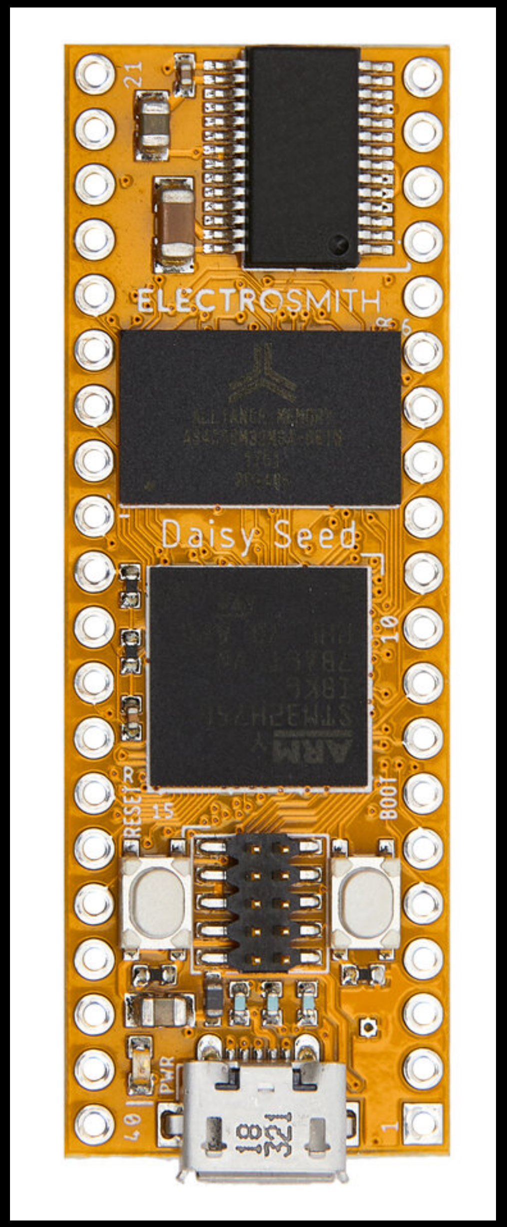


https://www.pjrc.com/teensy/td_libs_Audio.html

Bela

https://bela.io

Electrosmith Daisy



https://www.electro-smith.com/daisy

REFERENCES

- How Digital Audio Works
- Synthesis Fundamentals (Bob Moog Foundation)
- The Foundation of Synthesis [video series] (Bob Moog Foundation)
- Handmade Electronic Music: The Art of Hardware Hacking, Nicholas Collins (2009), Routledge, https://www.nicolascollins.com/handmade.htm
- The Computer Music Tutorial, Curtis Roads (1996), MIT Press.