DIGITAL MUSIC WORKSHOP / 00 / DIGITAL SOUND BASICS

DIGITAL MUSIC WORKSHOP / 00 / DIGITAL SOUND BASICS

- samples
- audio processing + synthesis
- programming audio

SAMPLES

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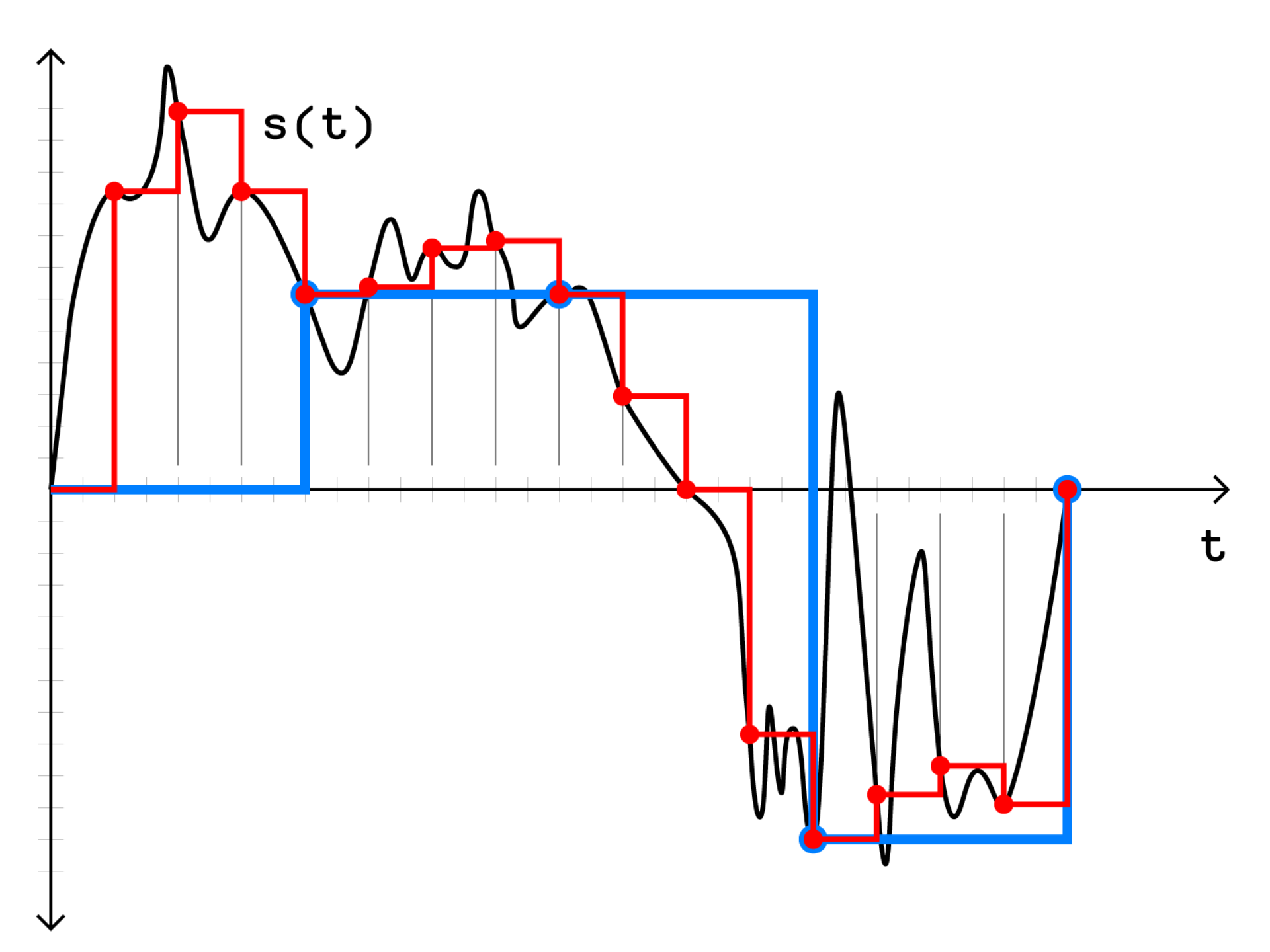
transforming a continous signal into a sequence of discrete numbers.


s(t)
t

SAMPLES

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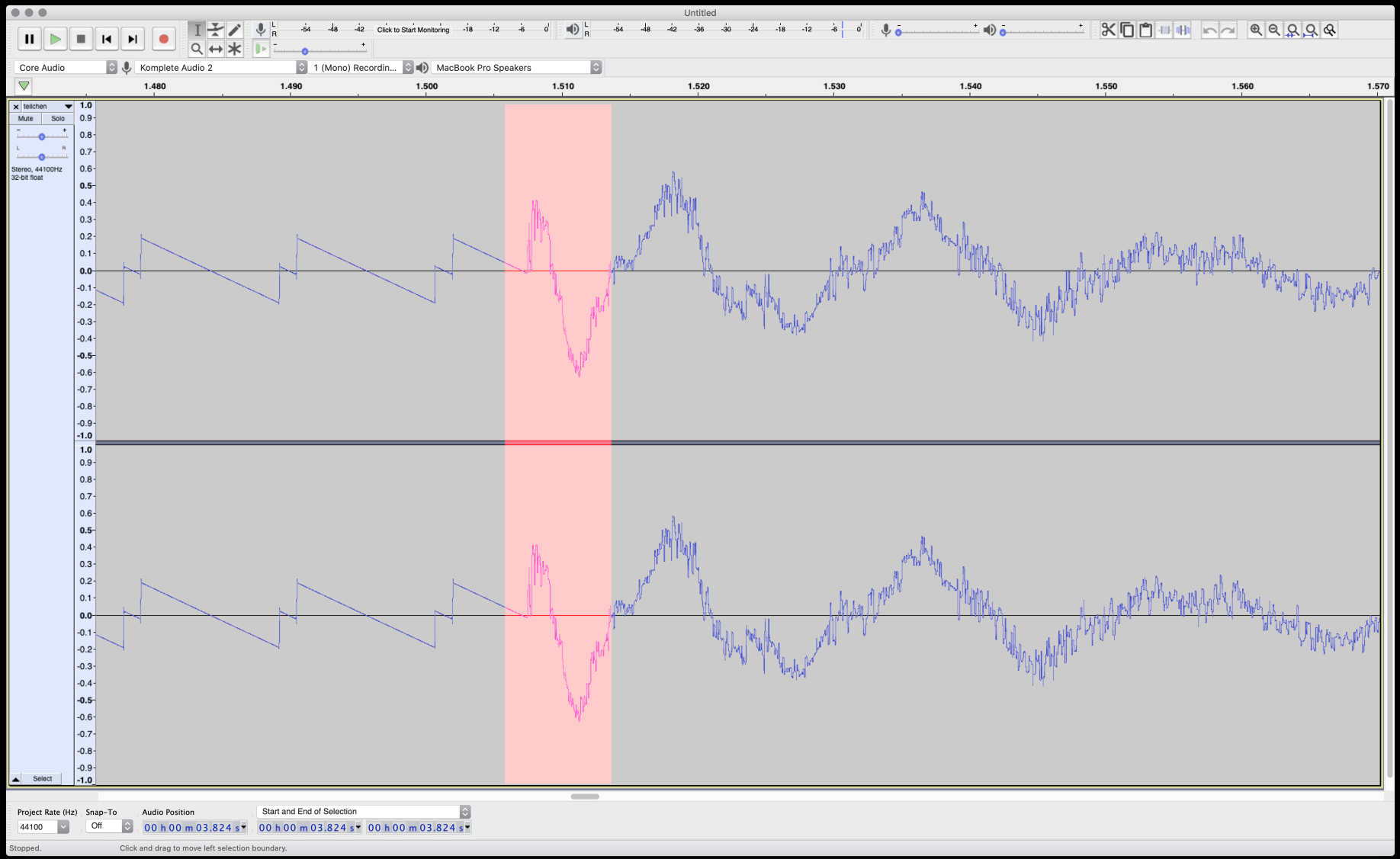
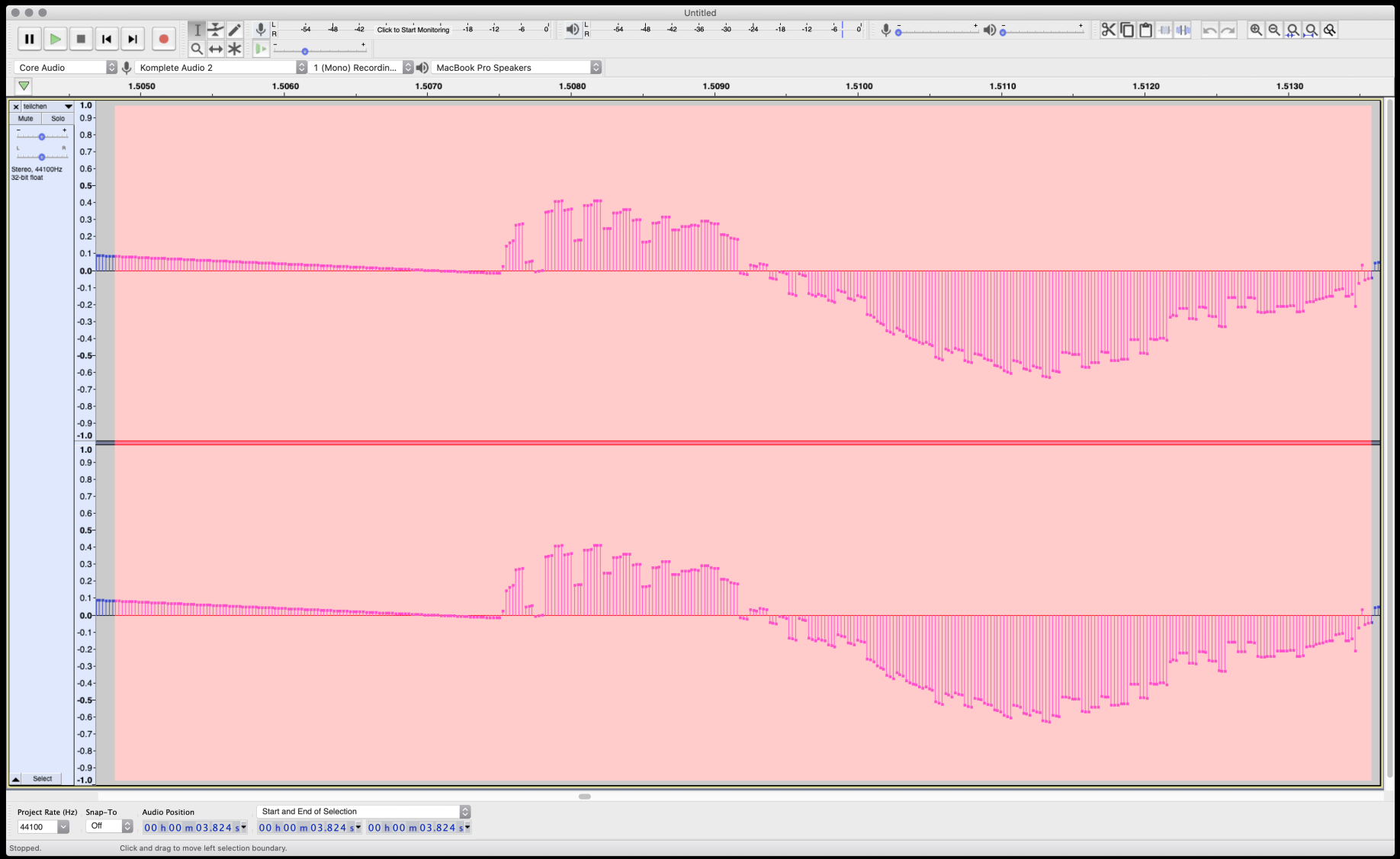
samples viewed in Audacity


Untitled
Click to Start Monitoring
Core Audio
Komplette Audio 2
1 (Mono) Recordin...
MacBook Pro Speakers
1.480
1.490
1.500
1.510
1.520
1.530
1.540
1.550
1.560
1.570
teilchen
Mute
Solo
Stereo, 44100Hz
32-bit float
Select
Project Rate (Hz)
44100
Snap-To
Off
Audio Position
00 h 00 m 03.824 s
Start and End of Selection
00 h 00 m 03.824 s
00 h 00 m 03.824 s
Stopped.
Click and drag to move left selection boundary.


Untitled
Click to Start Monitoring
Core Audio
Komplette Audio 2
1 (Mono) Recordin...
MacBook Pro Speakers
1.5050
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1.5080
1.5090
1.5100
1.5110
1.5120
1.5130
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Off
Audio Position
00 h 00 m 03.824 s
Start and End of Selection
00 h 00 m 03.824 s
00 h 00 m 03.824 s
Stopped.
Click and drag to move left selection boundary.

SAMPLES

HEX dump of WAV file 16 bits (= 2 bytes) per sample

```
00000860: C3 8D 17 C3 8D 1D C3 88 1D C3 88 1F C3 8B 1F C3 8B 35 C3 81 35 C3 81 C3 A2 C3 8A C3 A2 C3 8A C3   ..................5..5..........
00000880: 82 C3 82 C3 82 C3 82 48 C3 82 48 C3 82 E2 84 A2 E2 80 B0 E2 84 A2 E2 80 B0 0F E2 80 B0 0F E2 80   .......H..H.....................
000008A0: B0 74 E2 80 9E 74 E2 80 9E E2 82 AC E2 80 9A E2 82 AC E2 80 9A 3F E2 80 9A 3F E2 80 9A E2 80 A0   .t...t.............?...?.......
000008C0: C2 B7 E2 80 A0 C2 B7 CB 86 E2 80 A1 CB 86 E2 80 A1 43 E2 80 A1 43 E2 80 A1 C3 A0 EF AC 82 C3 A0   ..............C...C.............
000008E0: EF AC 82 C2 A0 EF AC 81 C2 A0 EF AC 81 09 EF AC 81 09 EF AC 81 49 E2 80 BA 49 E2 80 BA C3 A4 E2   ...................I...I......
00000900: 80 B9 C3 A4 E2 80 B9 C3 83 E2 82 AC C3 83 E2 82 AC 11 E2 82 AC 11 E2 82 AC 5B E2 81 84 5B E2 81   ...........................[...[..
00000920: 84 C2 A9 C5 B8 C2 A9 C5 B8 CB 9B C3 BF CB 9B C3 BF 5A C3 BF 5A C3 BF CE A9 E2 97 8A CE A9 E2 97   ..............Z..Z..............
00000940: 8A 27 E2 97 8A 27 E2 97 8A C3 B2 C3 B7 C3 B2 C3 B7 11 C3 B7 11 C3 B7 C3 AB E2 80 99 C3 AB E2 80   .'...'..........................
00000960: 99 16 E2 80 99 16 E2 80 99 C2 A2 E2 80 98 C2 A2 E2 80 98 37 E2 80 98 37 E2 80 98 E2 80 BA E2 80   ..................7...7........
00000980: 9D E2 80 BA E2 80 9D C3 B4 E2 80 9D C3 B4 E2 80 9D 68 E2 80 9D 68 E2 80 9D 43 E2 80 9D 43 E2 80   ..............h...h...C...C..
000009A0: 9D 22 E2 80 9D 22 E2 80 9D 02 E2 80 9D 02 E2 80 9D 9E E2 80 9C E2 80 9E E2 80 9C C6 92 E2   ."..."..........................
000009C0: 80 9C C6 92 E2 80 9C E2 80 A2 E2 80 9C E2 80 A2 E2 80 9C C3 A1 E2 80 9C C3 A1 E2 80 9C 68 E2 80   ..............................h..
000009E0: 9C 68 E2 80 9C 4A E2 80 9C 4A E2 80 9C 2B E2 80 9C 2B E2 80 9C 0D E2 80 9C 0D E2 80 9C C3 94 E2   .h...J...J...+...+..............

00000A00: 80 94 C3 94 E2 80 94 E2 80 93 E2 80 94 E2 80 93 E2 80 94 E2 89 A4 E2 80 94 E2 89 A4 E2 80 94 C3   ................................
00000A20: AE E2 80 94 C3 AE E2 80 94 76 E2 80 94 76 E2 80 94 58 E2 80 94 58 E2 80 94 3B E2 80 94 3B E2 80   .........v...v...X...X...;...;..
00000A40: 94 1D E2 80 94 1D E2 80 94 CB 87 E2 80 93 CB 87 E2 80 93 E2 80 9A E2 80 93 E2 80 9A E2 80 93 C6   ................................
00000A60: 92 E2 80 93 C6 92 E2 80 93 C2 B6 E2 80 93 C2 B6 E2 80 93 C3 A2 E2 80 93 C3 A2 E2 80 93 6B E2 80   ............................k..
00000A80: 93 6B E2 80 93 4E E2 80 93 4E E2 80 93 31 E2 80 93 31 E2 80 93 14 E2 80 93 14 E2 80 93 C2 AF C5   .k...N...N...1...1..............
00000AA0: 93 C2 AF C5 93 E2 80 B9 C5 93 E2 80 B9 C5 93 C2 AC C5 93 C2 AC C5 93 C2 A9 C5 93 C2 A9 C5 93 C3   ................................
00000AC0: AD C5 93 C3 AD C5 93 7C C5 93 7C C5 93 66 C5 93 66 C5 93 51 C5 93 51 C5 93 3C C5 93 3C C5 93 27   .......|..|..f..f..Q..Q..<..<..'
00000AE0: C5 93 27 C5 93 12 C5 93 12 C5 93 CB 9D C5 92 CB 9D C5 92 C3 8B C5 92 C3 8B C5 92 E2 80 9D C5 92   ..'.............................
00000B00: E2 80 9D C5 92 CE A9 C5 92 CE A9 C5 92 C2 AE C5 92 C2 AE C5 92 C3 AC C5 92 C3 AC C5 92 7D C5 92   ..............................}..
00000B20: 7D C5 92 68 C5 92 68 C5 92 52 C5 92 52 C5 92 3D C5 92 3D C5 92 27 C5 92 27 C5 92 11 C5 92 11 C5   }..h..h..R..R..=..=..'..'.......
00000B40: 92 CB 9A C3 95 CB 9A C3 95 C3 82 C3 95 C3 82 C3 95 C5 93 C3 95 C5 93 C3 95 CF 80 C3 95 CF 80 C3   ................................
00000B60: 95 C2 A3 C3 95 C2 A3 C3 95 C3 A7 C3 95 C3 A7 C3 95 77 C3 95 77 C3 95 61 C3 95 61 C3 95 4A C3 95   .................w..w..a..a..J..
00000B80: 4A C3 95 34 C3 95 34 C3 95 1E C3 95 1E C3 95 08 C3 95 08 C3 95 C3 9A C3 83 C3 9A C3 83 E2 80 B9   J..4..4.........................
00000BA0: C3 83 E2 80 B9 C3 83 E2 80 A6 C3 83 E2 80 A6 C3 83 C3 B8 C3 83 C3 B8 C3 83 C2 AC C3 83 C2 AC C3   ................................
00000BC0: 83 E2 80 93 C3 83 E2 80 93 C3 83 C3 8B C3 83 C3 8B C3 83 03 C3 95 03 C3 95 21 C3 95 21 C3 95 40   ..........................!..!..@
00000BE0: C3 95 40 C3 95 62 C3 95 62 C3 95 C3 96 C3 95 C3 96 C3 95 C2 B4 C3 95 C2 B4 C3 95 E2 80 9C C3 95   ..@..b..b.......................

00000C00: E2 80 9C C3 95 C2 B8 C3 95 C2 B8 C3 95 28 C5 92 28 C5 92 57 C5 92 57 C5 92 62 C5 92 62 C5 92 C3   .............(..(..W..W..b..b...
00000C20: 80 C5 93 C3 80 C5 93 E2 89 A0 C3 80 E2 89 A0 C3 80 C3 A2 C2 B7 C3 A2 C2 B7 60 C3 8C 60 C3 8C C3   ..........................`..`...
00000C40: 96 C3 8D C3 96 C3 8D C3 A3 C3 8E C3 A3 C3 8E C2 BF C3 8E C2 BF C3 8E 03 C3 8F 03 C3 8F 48 C3 8F   ..............................H..
00000C60: 48 C3 8F C3 A8 C3 8F C3 A8 C3 8F C5 B8 C3 8F C5 B8 C3 8F 24 C3 8C 24 C3 8C 71 C3 8C 71 C3 8C C2   H..................$..$..q..q...
00000C80: BF C3 8C C2 BF C3 8C 10 C3 93 10 C3 93 62 C3 93 62 C3 93 C2 B5 C3 93 C2 B5 C3 93 09 C3 94 09 C3   .............b..b...............
00000CA0: 94 5E C3 94 5E C3 94 C2 B5 C3 94 C2 B5 C3 94 0D EF A3 BF 0D EF A3 BF 67 EF A3 BF 67 EF A3 BF C2   .^..^..................g...g.....
00000CC0: AC EF A3 BF C2 AC EF A3 BF 1F C3 92 1F C3 92 7D C3 92 7D C3 92 E2 80 B9 C3 92 E2 80 B9 C3 92 3D   ..............}..}.............=
00000CE0: C3 9A 3D C3 9A C3 BC C3 9A C3 BC C3 9A 02 C3 9B 02 C3 9B 66 C3 9B 66 C3 9B C3 83 C3 9B C3 83 C3   ..=.................f..f.........
00000D00: 9B 33 C3 99 33 C3 99 C3 B5 C3 99 C3 B5 C3 99 05 C4 B1 05 C4 B1 70 C4 B1 70 C4 B1 E2 80 B9 C4 B1   .3..3.............p..p.........
00000D20: E2 80 B9 C4 B1 49 CB 86 49 CB 86 E2 88 91 CB 86 E2 88 91 CB 86 26 CB 9C 26 CB 9C C3 B1 CB 9C C3   .....I..I...........&..&.......
00000D40: B1 CB 9C 07 C2 AF 07 C2 AF 79 C2 AF 79 C2 AF C3 8F C2 AF C3 8F C2 AF 5F CB 98 5F CB 98 E2 80 9D   .........y..y.........._.._.....
00000D60: CB 98 E2 80 9D CB 98 48 CB 99 48 CB 99 C3 A6 CB 99 C3 A6 CB 99 34 CB 9A 34 CB 9A E2 84 A2 CB 9A   .......H..H.........4..4........
00000D80: E2 84 A2 CB 9A 21 C2 B8 21 C2 B8 C3 B3 C2 B8 C3 B3 C2 B8 0E CB 9D 0E CB 9D C3 96 CB 9D C3 96 CB   .....!..!.......................
00000DA0: 9D CB 9A CB 9D CB 9A CB 9D 72 CB 9B 72 CB 9B C3 81 CB 9B C3 81 CB 9B 5B CB 87 5B CB 87 C5 92 CB   .........r..r.........[..[......
00000DC0: 87 C5 92 CB 87 3F 00 3F 00 C3 86 00 C3 86 00 19 01 19 01 C3 84 01 C3 84 01 E2 80 9A 01 E2 80 9A   .....?.?.......................
00000DE0: 01 40 02 40 02 C3 B4 02 C3 B4 02 C3 94 02 C3 94 02 42 03 42 03 C3 AE 03 C3 AE 03 E2 80 B0 03 E2   .@.@..........B.B...............

00000E00: 80 B0 03 34 04 34 04 C3 89 04 C3 89 04 E2 80 9C 04 E2 80 9C 04 20 05 20 05 6F 05 6F 05 C2 BA 05   ...4.4.............. . .o.o.....
00000E20: C2 BA 05 0A 06 0A 06 57 06 57 06 E2 80 A2 06 E2 80 A2 06 C3 9A 06 C3 9A 06 4D 07 4D 07 E2 80 9C   .......W.W.............M.M.....
00000E40: 07 E2 80 9C 07 57 08 57 08 E2 82 AC 08 E2 82 AC 08 5F 09 5F 09 E2 80 9E 09 E2 80 9E 09 66 0A 66   .....W.W........._._.........f.f
00000E60: 0A C3 8D 0A C3 8D 0A 6D 0B 6D 0B EF A3 BF 0B EF A3 BF 0B 72 0C 72 0C C4 B1 0C C4 B1 0C 76 0D 76   .......m.m.........r.r.......v.v
00000E80: 0D C2 AF 0D C2 AF 0D 78 0E 78 0E CB 98 0E CB 98 0E 78 0F 78 0F CB 86 0F CB 86 0F 74 10 74 10 C3   .......x.x.......x.x.......t.t..
00000EA0: 9A 10 C3 9A 10 6E 11 6E 11 C3 88 11 C3 88 11 64 12 64 12 E2 80 BA 12 E2 80 BA 12 55 13 55 13 C3   .....n.n.......d.d.........U.U..
00000EC0: 95 13 C3 95 13 43 14 43 14 E2 88 8F 14 E2 88 8F 14 2C 15 2C 15 C3 BB 15 C3 BB 15 10 16 10 16 C3   .....C.C.........,.,............
00000EE0: 84 16 C3 84 16 C3 94 16 C3 94 16 5C 17 5C 17 C2 BB 17 C2 BB 17 33 18 33 18 C3 BA 18 C3 BA 18 04   ...........\.\.........3.3......
00000F00: 19 04 19 6A 19 6A 19 C5 93 19 C5 93 19 32 1A 32 1A C3 AF 1A C3 AF 1A C3 99 1A C3 99 1A 55 1B 55   ...j.j.........2.2.............U.U
00000F20: 1B C3 BC 1B C3 BC 1B C2 AB 1B C2 AB 1B C3 9B 1B C3 9B 1B 1C 1C 1C 1C 45 1C 45 1C 6C 1C 6C 1C C3   ..........................E.E.l.l..
```

SAMPLES

- common sample rate + sample depth
  - 44.100Hz, 16bit (CD quality)
  - 48.000Hz, 24bit (more *recent* digital system)
- common sample value range: `FLOAT(-1.0, 1.0)`
- Digital-Analog Converters (DAC) convert samples into analog audio signals
- Analog-Digital Converters (ADC) convert analog audio signals into samples

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AUDIO PROCESSING + SYNTHESIS

- oscillators
- filters
- envelopes
- effects
- analysis

OSCILLATOR
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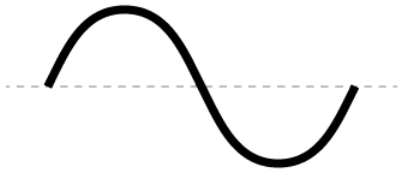
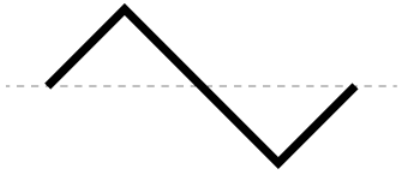
oscillator repeatingly create signals at specific frequencies.
oscillators are destinguished by the *waveforms* they produce.

the most common waveforms or -shapes are:

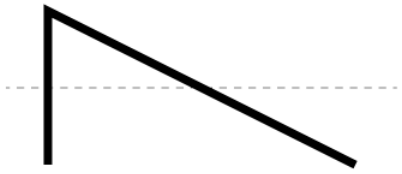
- sine
- triangle
- sawtooth
- square



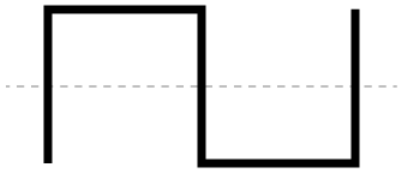
sine



triangle



sawtooth



square

OSCILLATOR

- in reference to their electronic origins oscillators are sometimes still refered to as *Voltage-Controlled Oscillators* (VCO).
- oscillators that oscillate at low frequencies (< 20Hz) are refered to as *Low Frequency Oscillators* (LFO).
- *wavetables* are pieces of memory containing waveforms (or other sample data). in audioprogramming wavetables are sometimes used to implement oscillators.
- *oscilloscopes* are used to visualize signals.
- @example(`ExampleDSP05Wavetable`)

FILTERS
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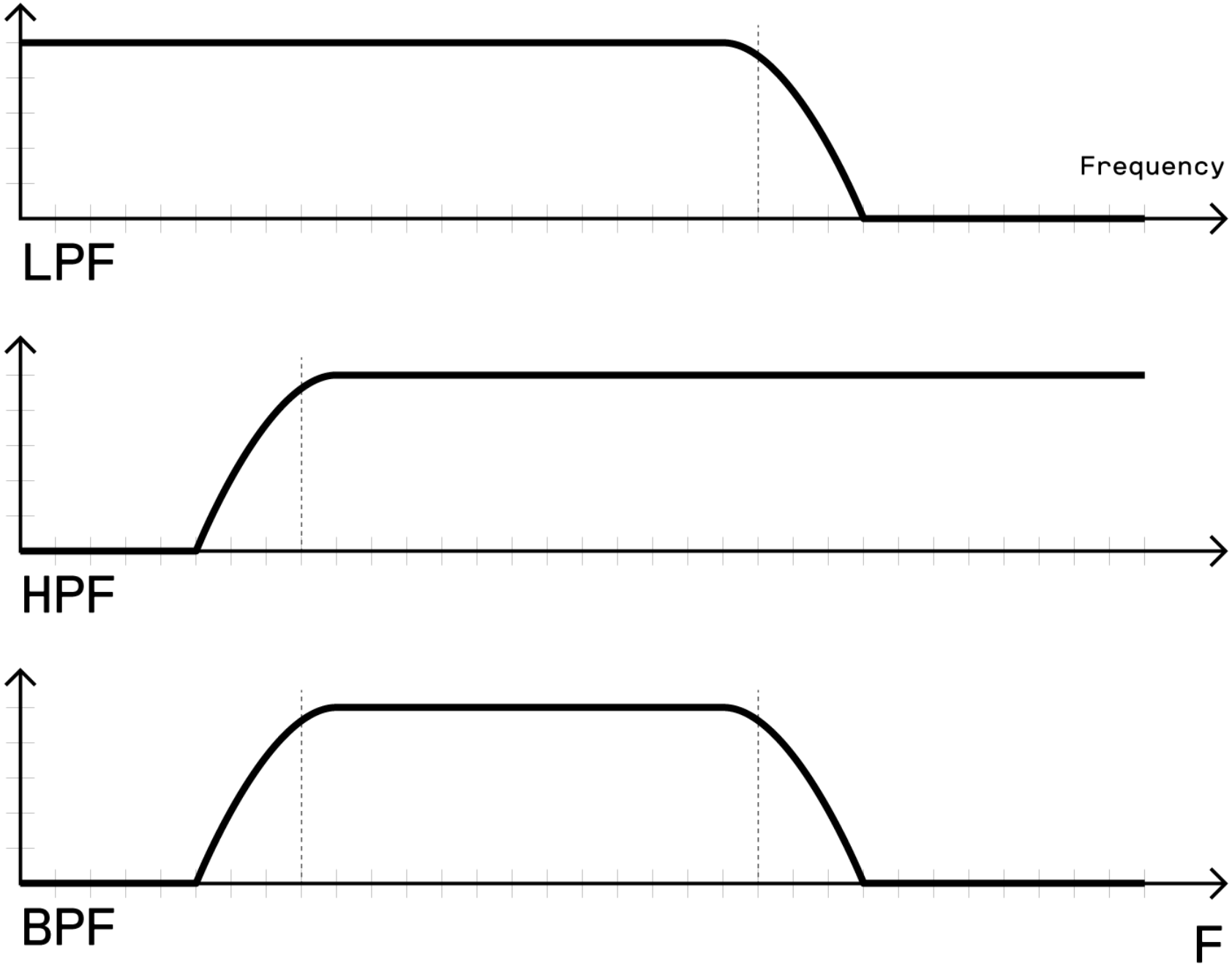
filters are processes that remove unwanted components or features (often frequencies) from a signals.

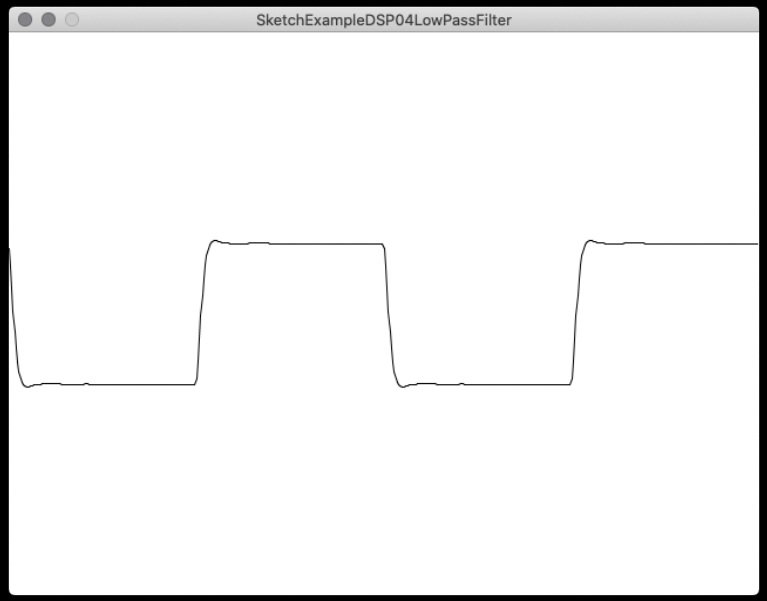
the most common filters are:

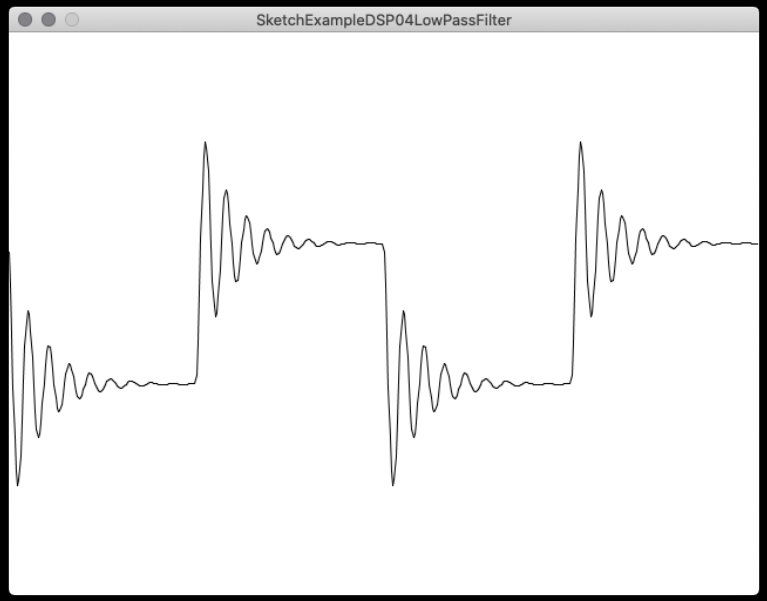
- Low Pass Filter (LPF)
- High Pass Filter (HPF)
- Band Pass Filter (BPF)


Frequency
LPF
HPF
BPF
F

FILTERS

- in reference to their electronic origins filters are still sometimes refered to as *Voltage-Controlled Filters* (VCF)
- 2 common paramters in filters are
  - *CutOff Frequency*
  - *Resonance* (`Q` or quality factor)
- @example(`ExampleDSP04LowPassFilter`)


SketchExampleDSP04LowPassFilter


SketchExampleDSP04LowPassFilter

ENVELOPES

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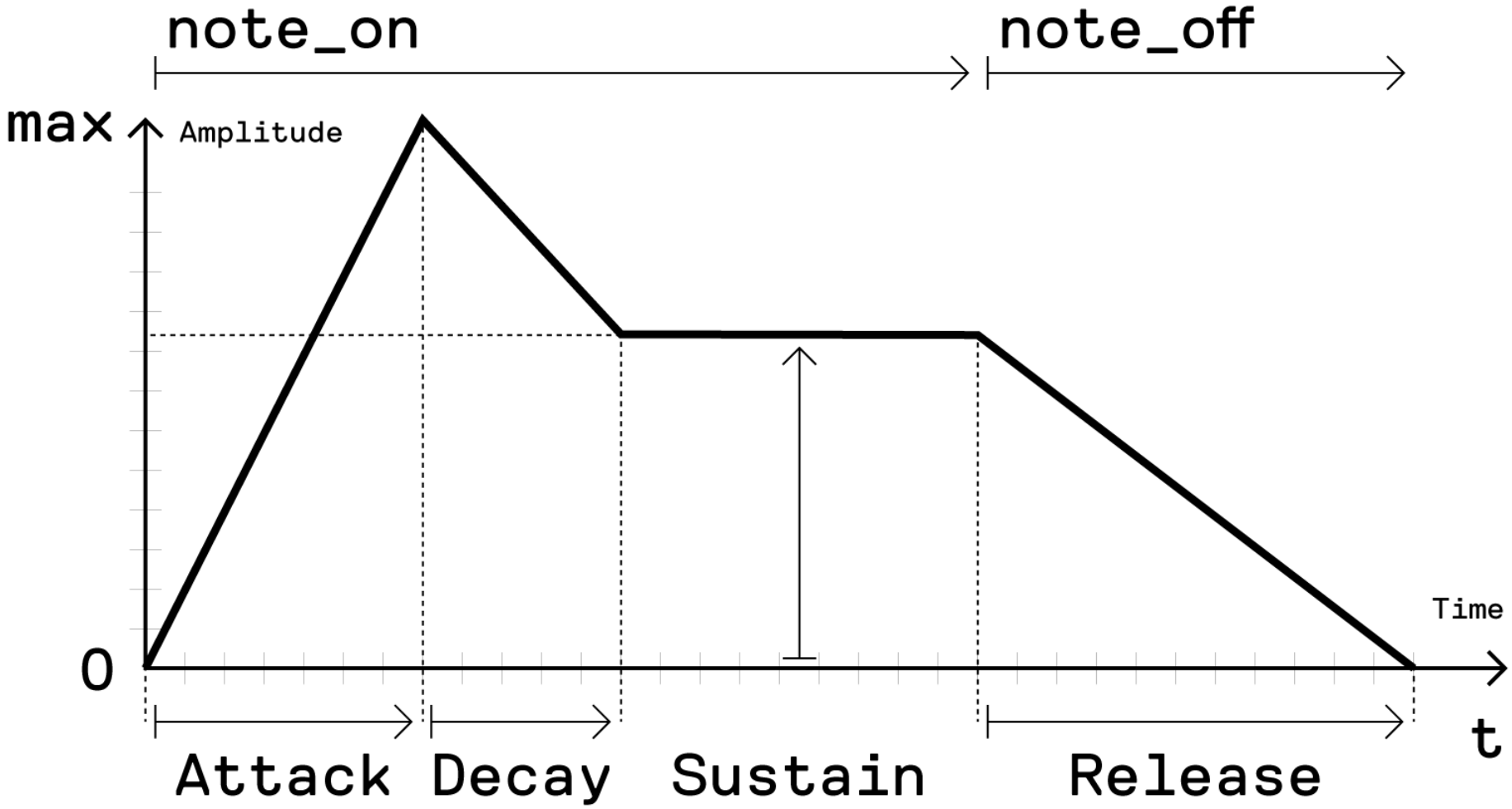
envelopes describe parameter changes over time.

the most common envelope is the *Attack-Decay-Sustain-Release envelope* (ADSR).


note_on
note_off
max
Amplitude
0
Time
t
Attack
Decay
Sustain
Release

ENVELOPES

- ADSR envelope synth tutorial part A
- ADSR envelope synth tutorial part B
- @example(ExampleInstruments01ADSR)
- note that envelopes can be applied to other paramters as well
  e.g filter or effect values.

EFFECTS

- delay/echo
- reverb
- chorus
- @example(`ExampleDSP03Echo`)

ANALYSIS

- Peak Follower
- Beat Detection
- Fast Fourier Transformation (FFT) (for an explanation on FFT see 3Blue1Brown: But what is the Fourier Transform? A visual introduction.)

SUMMARY

- Subtractive Synthesis (+ Additive Synthesis)
- Digital Signal Processing (DSP)
- analog + digital Modular Synthesizer (see also Eurorack)
- @REF(Curtis Roads: The Computer Music Tutorial)
- @REF(Music DSP)

PROGRAMMING AUDIO

- visual (nodes + flow) versus text-based (block)
- visual
  - Max
  - Pure Data
- text-based
  - SuperCollider
  - Csound
  - Processing.org (Libraries)

AUDIO APPLICATIONS

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an incomplete list of some common audio applications:

- Max @visualprogramming
- Pure Data @visualprogramming
- SuperCollider @text-based
- Csound @text-based
- Abelton Live @DAW
- Logic Pro / GarageBand @DAW
- REAPER @DAW
- Bitwig Studio @DAW
- VCV Rack @modularsynthsimulator
- Audacity @audio-editor
- ocenaudio @audio-editor

TON

Ton a framework for exploring and teaching generative music making and algorithmic compositions. it facilitates simple ways of playing musical notes, facilitates easy access to low-level digital signal processing (DSP) and supplies rhythm and timing as well as some standard muscial mechanics. the library acts as a simple adapter to various sound in- and outputs like JSyn, MIDI, OSC, or analog audio.

TON

- `Ton` playing notes
- `DSP` processing sound
- `Beat` creating rhythm