FREQUENCY, PITCH, AND SIGNALS

In Automatonism & PureData

Frequency and Musical Pitches

- Frequency is in cycles per second (cps)
    - or Hertz
- Pitches are defined as ratios
    - often relative to a 'root'
    - 'A440' is the pitch reference for orchestras

JUST INTONATION

Pythagoras gets credit for discovering:

- simple ratios create pleasing intervals
- octave: [2/1]
- Major chord: [1, 5/4, 3/2]
- Major scale: [1, 9/8, 5/4, 4/3, 3/2, 5/3, 15/8, 2/1]
- These simple ratios are called **Just Intonation**

Chromatic scale:

Interval	Degree	Ratio
Root	0	1/1
Minor 2nd	1	16/15
Major 2nd	2	9/8
Minor 3rd	3	6/5
Major 3rd	4	5/4
Perfect 4th	5	4/3
Tritone	6	45/32
Perfect 5th	7	3/2
Minor 6th	8	8/5
Major 6th	9	5/3
Minor 7th	10	9/5
Major 7th	11	15/8
Octave	12	2/1

THE TRANSPOSITION PROBLEM

A major chord built on the root sounds good:
`[0,5/4,3/2] = [1, 1.25, 1.5]`

A major chord built on the 5th sound good:
`[3/2,15/8,18/8] = [1.5, 1.875, 2.25] = [1, 1.25, 1.5]`

A major chord built on the 3rd, not so much
`[5/4,8/5,15/8] = [1.25, 1.6, 1.875] = [1, 1.28, 1.5]`

Root	Root	Third	Fifth
C	1.00	1.25	1.50
C#	1.00	1.25	1.50
D	1.00	1.25	1.48
D#	1.00	1.25	1.50
E	1.00	1.28	1.50
F	1.00	1.25	1.50
F#	1.00	1.28	1.517
G	1.00	1.25	1.50
G#	1.00	1.25	1.50
A	1.00	1.28	1.48
A#	1.00	1.28	1.50
B	1.00	1.25	1.50

EQUAL TEMPERAMENT

'Tempers' the fifth by flatting it slightly

- makes all notes 'slightly' out of tune
- but all chords have the same ratios!
- often called **12-TET**
  - 12-tone equal temperament

The formula: ratio = 2^(N/12)

- where N is the # of half-steps
- 2^(1/12) = 1.059
- 2^(4/12) = 1.2599
- 2^(7/12) = 1.498
- 2^(12/12) = 2.0

what frequency in Hz is middle C? A = 440 C = 9 steps below A 2^(-9/12) * 440 = ??

MIDI NOTES

Musical instrument digital interface

- established in 1983
- standard protocal for sending musical data

MIDI pitches

- chromatic pitches 0-127
- MIDI note 60 is middle C
- an octave is 12, so C=[36,48,60,72]
- easy way to think and work with notes

MUSICAL SCALES

Mostly we don't use the chromatic scale as-is

- we create other scales as subsets
- Major scale: [0,2,4,5,7,9,11] (Ionian)
- Minor scale: [0,2,3,5,7,8,10] (Aeolian)
- Pentatonic scale: [0,2,4,7,9]

Chords are typically every other note of a scale,

- Major chord: [0,4,7]
- Minor chord: [0,3,7]

Referencing scales by *scale degree*

- Triads (1,3,5) = scale[0],[2],[4]
- 7th chord (1,3,5,7) = scale[0],[2],[4],[6]

TRIAD REPRESENTATIONS

Represented as scale degrees:

Major Triad	0		2	4			7
Major scale	0	1	2	3	4	5	6	7

Represented as chromatic degrees:

Major Triad	0				4		7					12
Major scale	0		2		4	5		7		9		11	12
Chromatic	0	1	2	3	4	5	6	7	8	9	10	11	12

ANALOG PITCH REPRESENTATIONS

Analog synthesizers represent pitch as *voltage*

Two standards:

- 1V / octave
    - linear pitch, exponential frequency
    - each volt goes up an octave
    - most common, by far
- Hertz / volt
    - linear frequency
    - exponential pitch, octaves = [0.5,1,2,4]
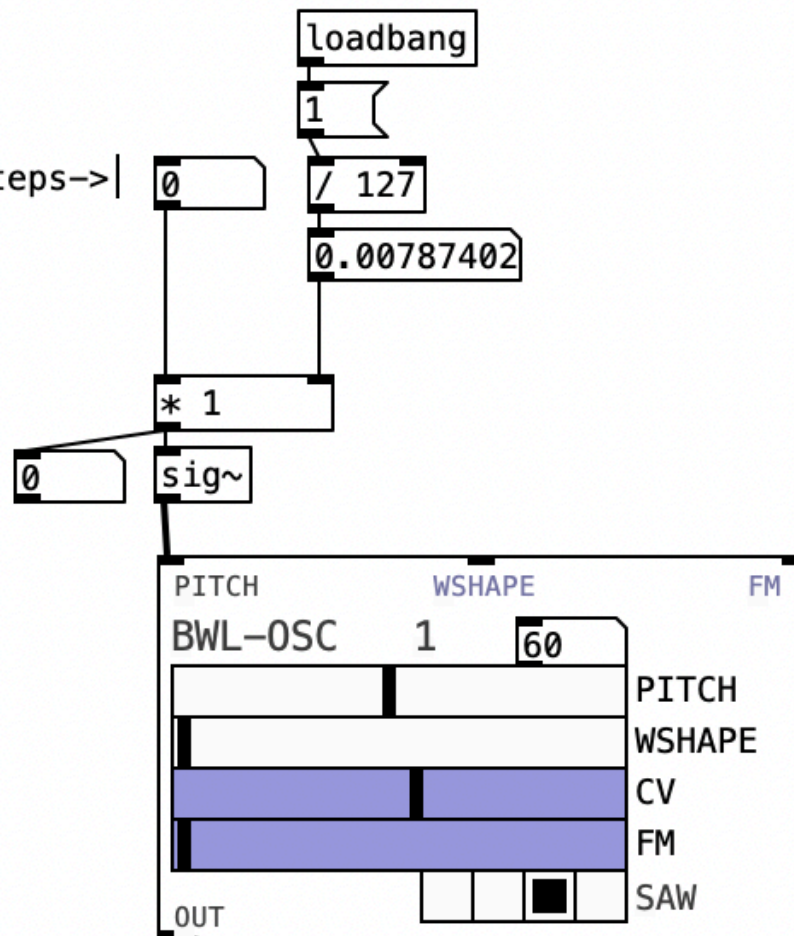
AUTOMATONISM PITCH REPRESENTATION

Represents full MIDI note range (0-127) as (0-1)

- each chromatic note increases by 1/127
- an octave is 12/127
- quantizers output a few octaves

But how do we represent just intonation?

- we have to reverse engineer from 12-tet!
- 12-TET: ratio = 2^(N/12)
- Automatonism octave: 12/127 = 0.09449...
- Just formula: `log2(ratio) * (12/127)`
- let's do this in python...

loadbang

1

enter chromatic steps->| 0

/ 127

0.00787402

* 1

0   sig~

PITCH   WSHAPE   FM

BWL-OSC   1   60

PITCH

WSHAPE

CV

FM

SAW

OUT

AUTOMATONISM OSCILLATORS

- Pitch input expects (0-1) values
- Pitch *slider* is in MIDI notes!
- FM (frequency modulation) input is ???
- Filter cutoff inputs are ???
- Don't worry about it!
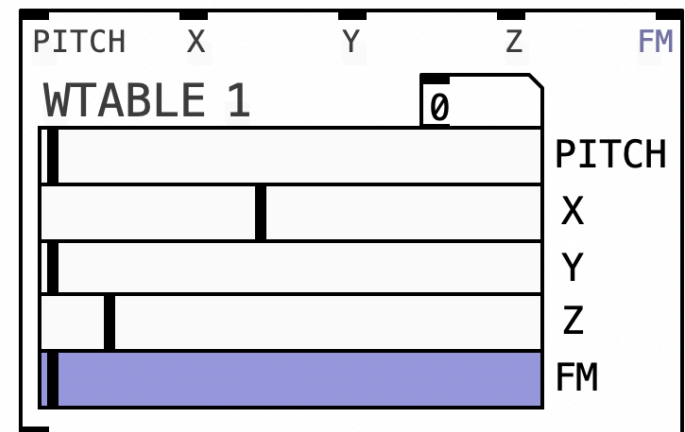
SIGNALS AND CONTROL MESSAGES

Audio needs to be continuously generated

- 48000 values per second!
- requires dedicated signals
- all automatonism modules are audio!!!
- in PD: thick lines, modules use ~ tilde
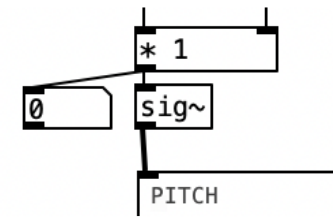
Control messages are only sent when triggered

- 1 message per trigger
- in PD thin lines
- convert to audio using `sig~`
- all messages outside PD are control rate!

CONTROL AUTOMATONISM PARAMETERS

MOST parameters for automatonism modules can be easily controlled remotely

You target a parameter by:

- module name (lowercase)
- module instance number
- parameter name (CAPITALS)

Modules with the same name and instance number receive the same messages!