Sound and waveforms

Valerio Velardo

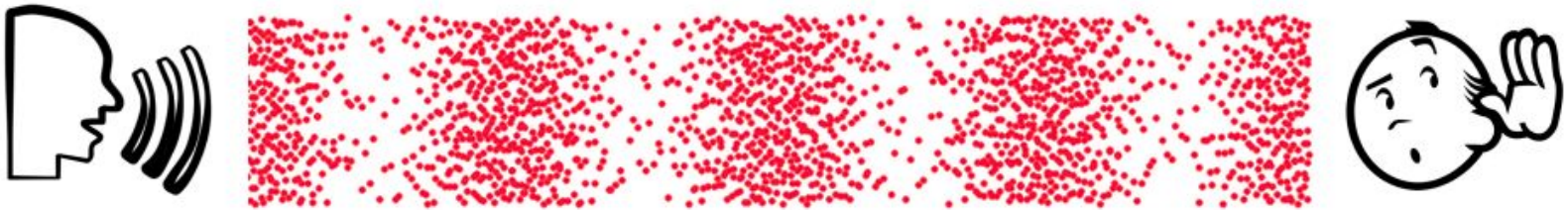
Sound

- Produced by vibration of an object
- Vibrations cause air molecules to oscillate
- Change in air pressure creates a wave

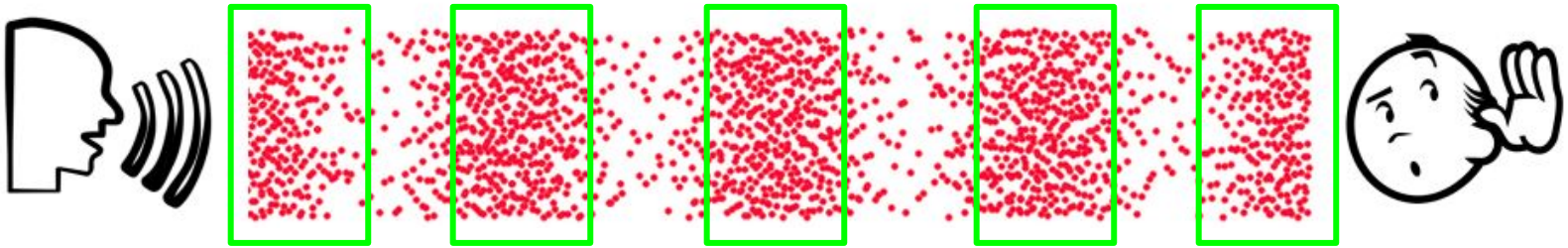
Mechanical wave

- Oscillation that travels through space
- Energy travels from one point to another
- The medium is deformed

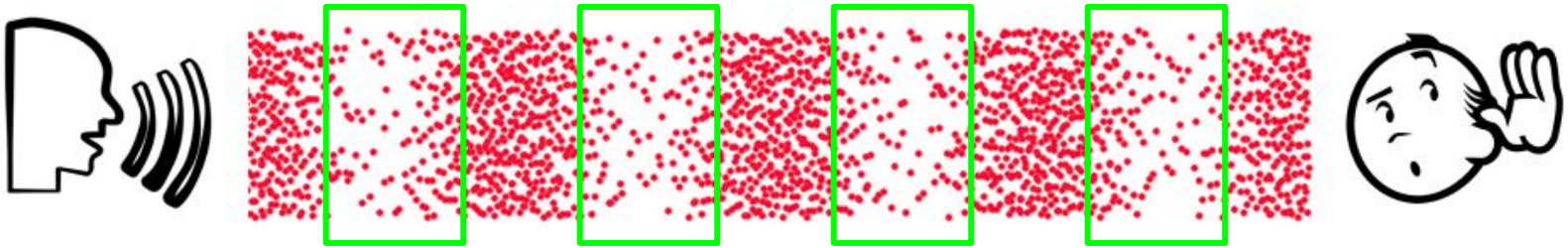
Sound wave



Sound wave

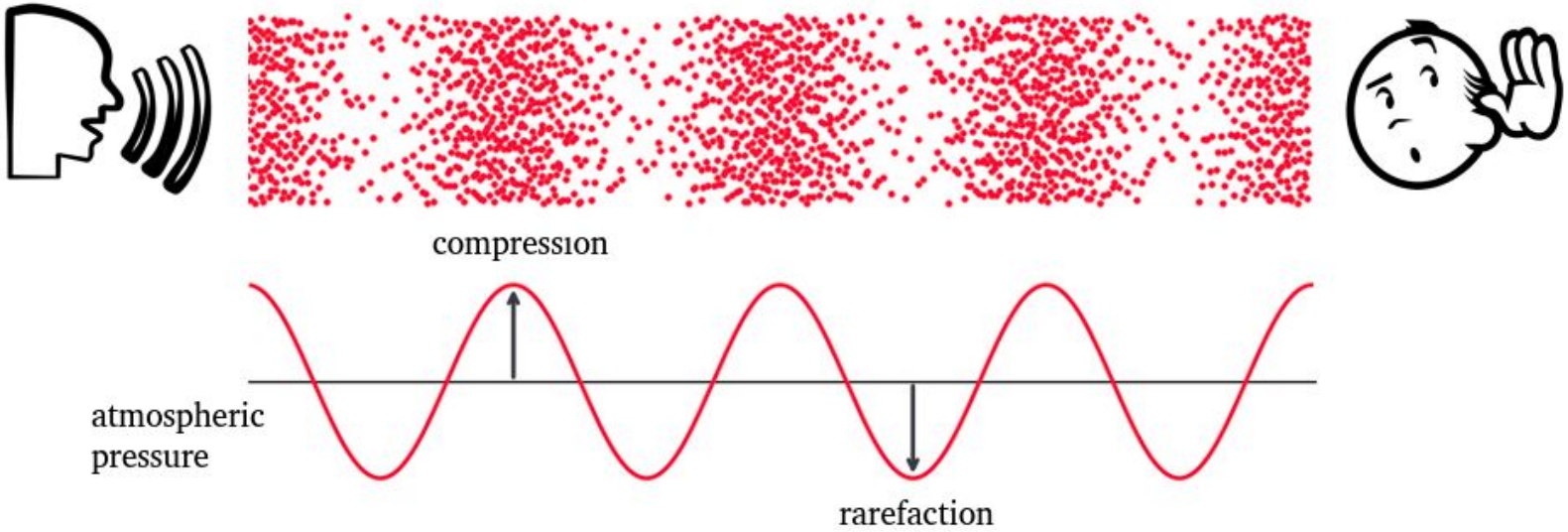


Sound wave

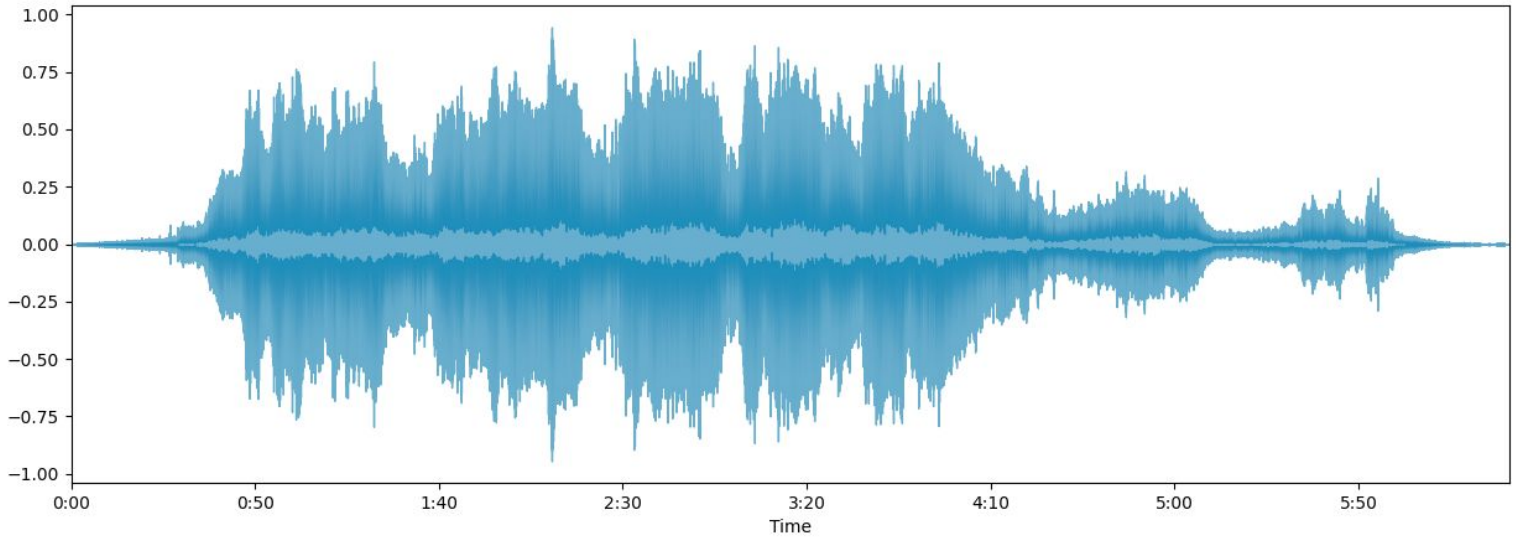


Sound wave

Sound wave



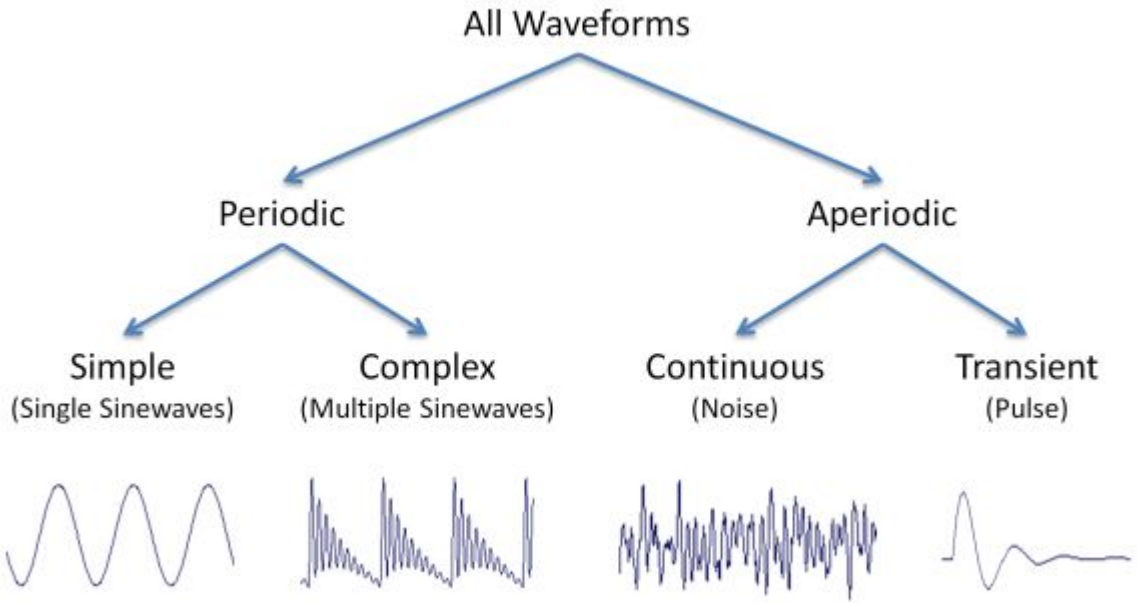
Waveform


1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0:00
0:50
1:40
2:30
3:20
4:10
5:00
5:50
Time

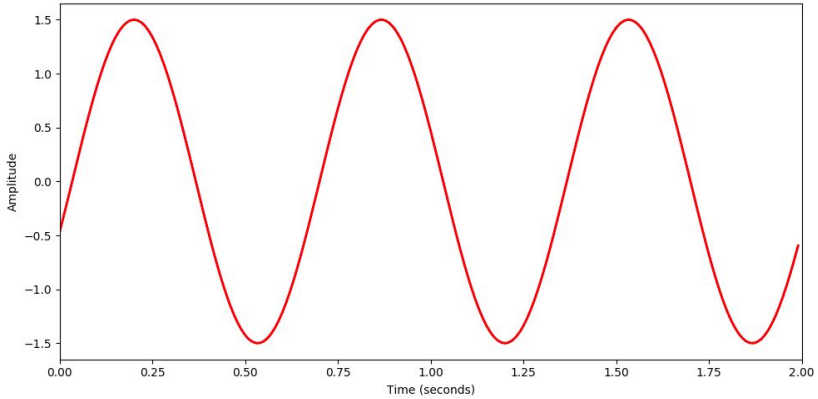
Waveform

- Carries multifactorial information:
  - Frequency
  - Intensity
  - Timbre 音色

Periodic and aperiodic sound

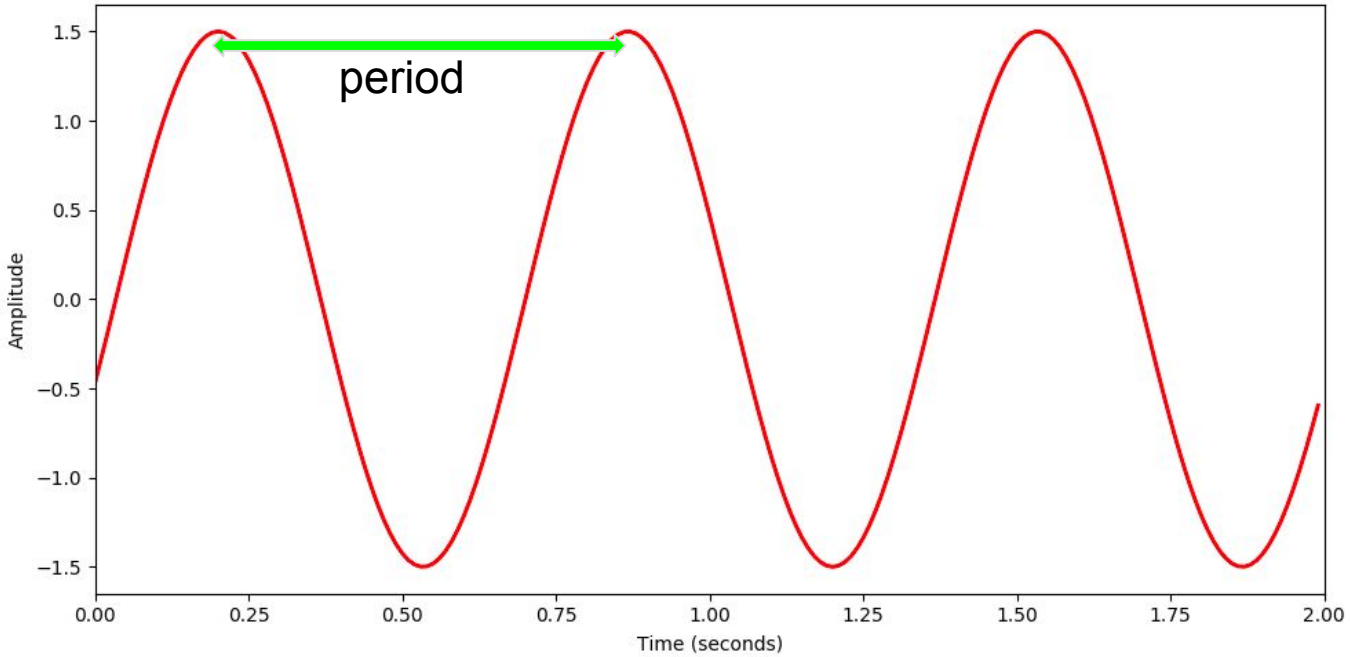


Waveform

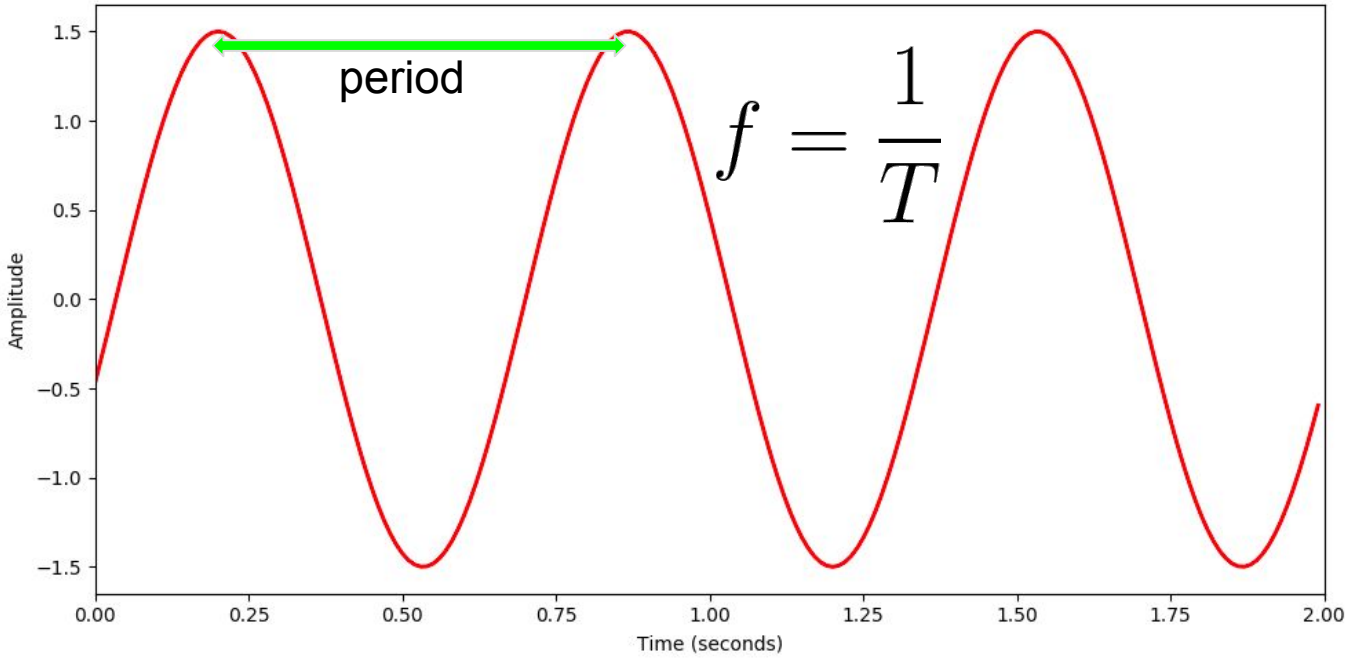


$$y(t) = A\sin(2\pi f t + \varphi)$$

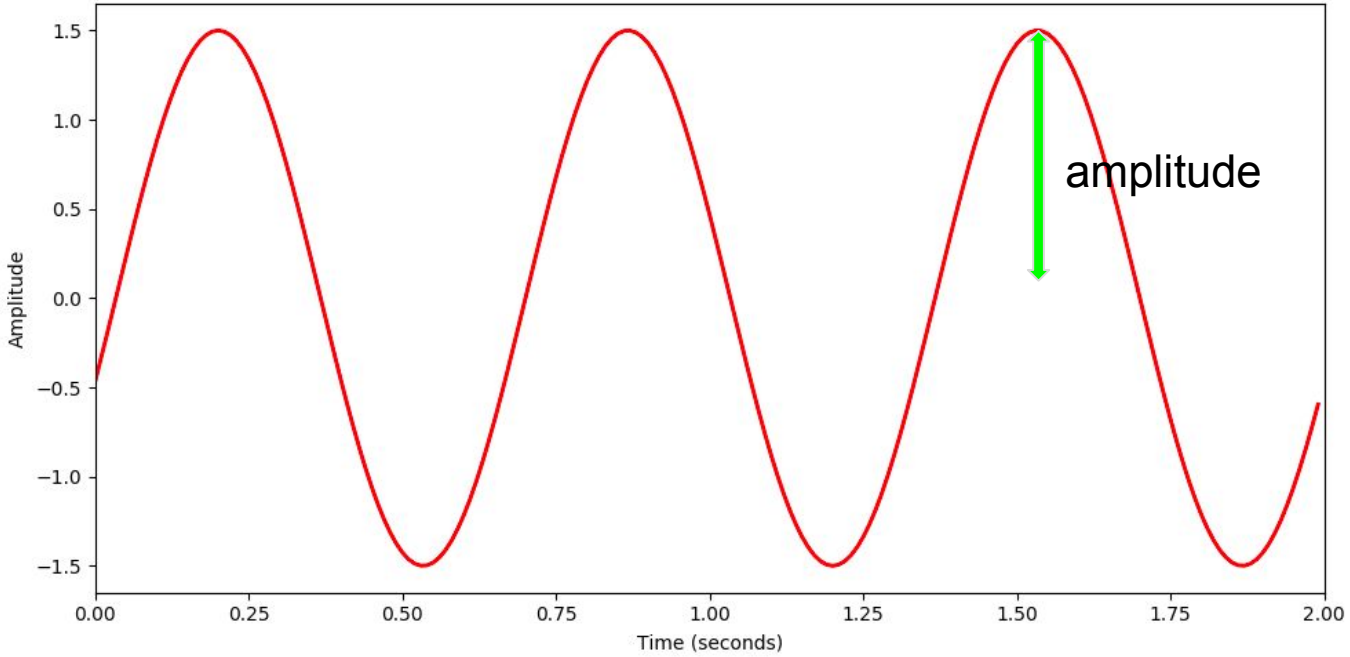
Frequency


period
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
Amplitude
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Time (seconds)

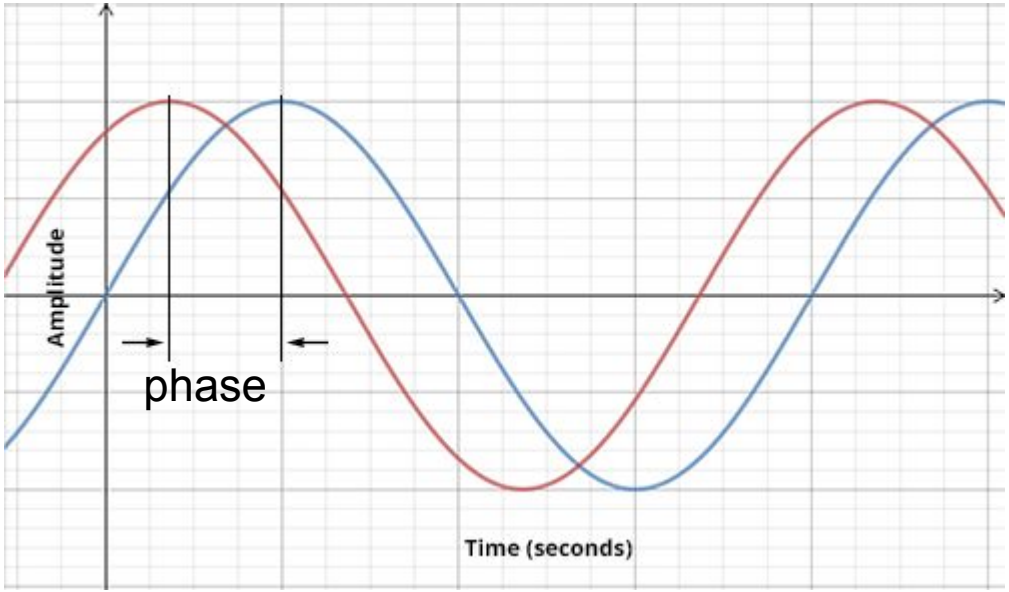
Frequency


period
$f = \frac{1}{T}$
Amplitude
Time (seconds)
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00

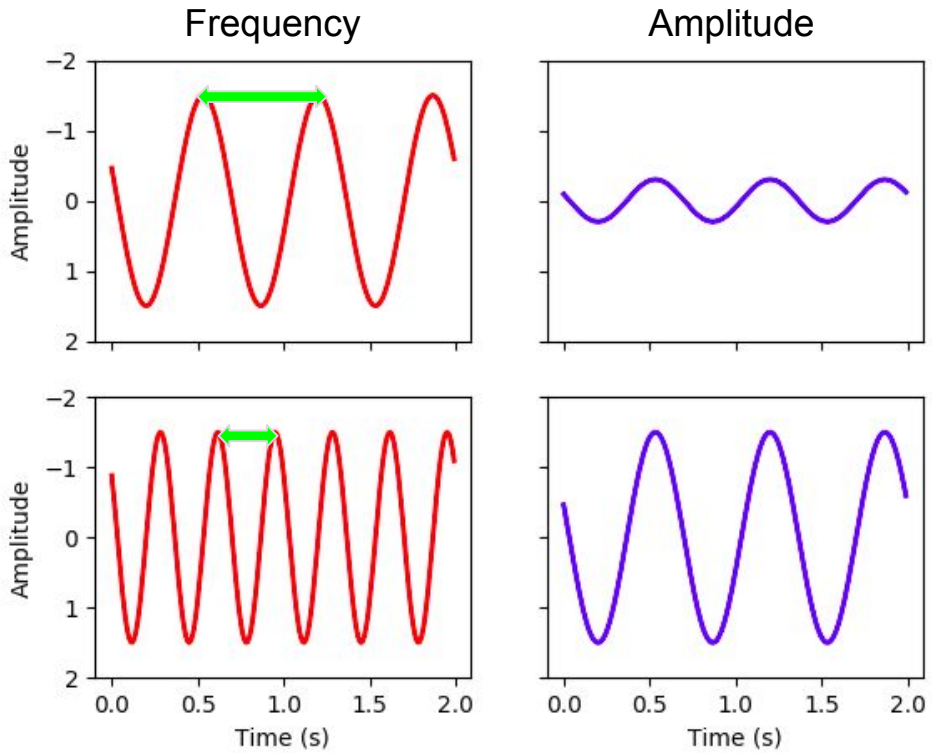
Amplitude


amplitude
Amplitude
Time (seconds)
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00

Phase

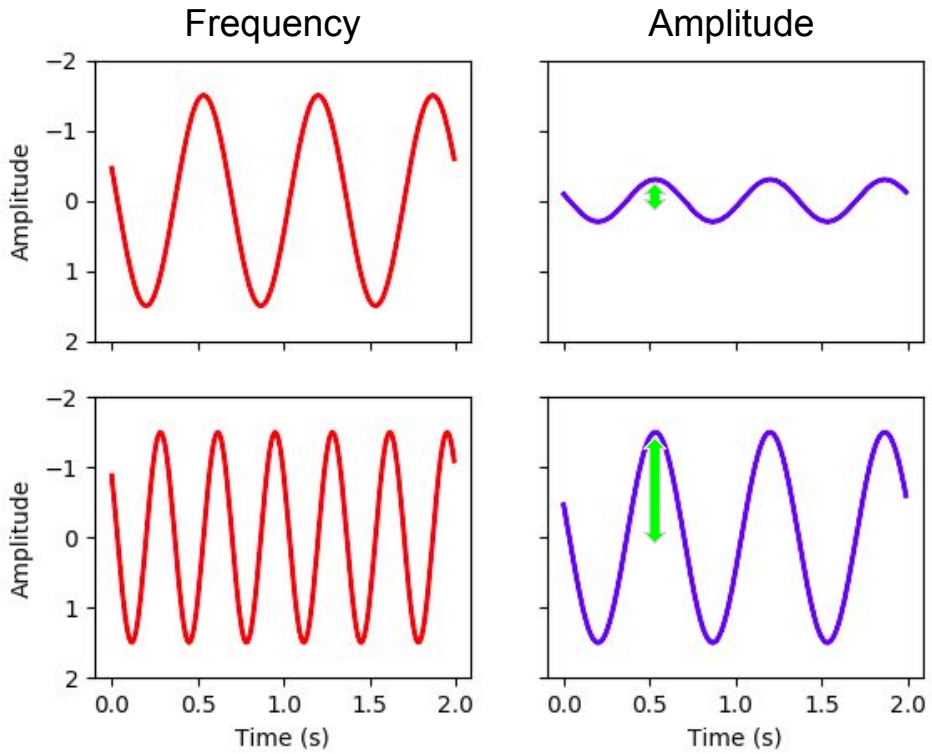


Frequency and amplitude



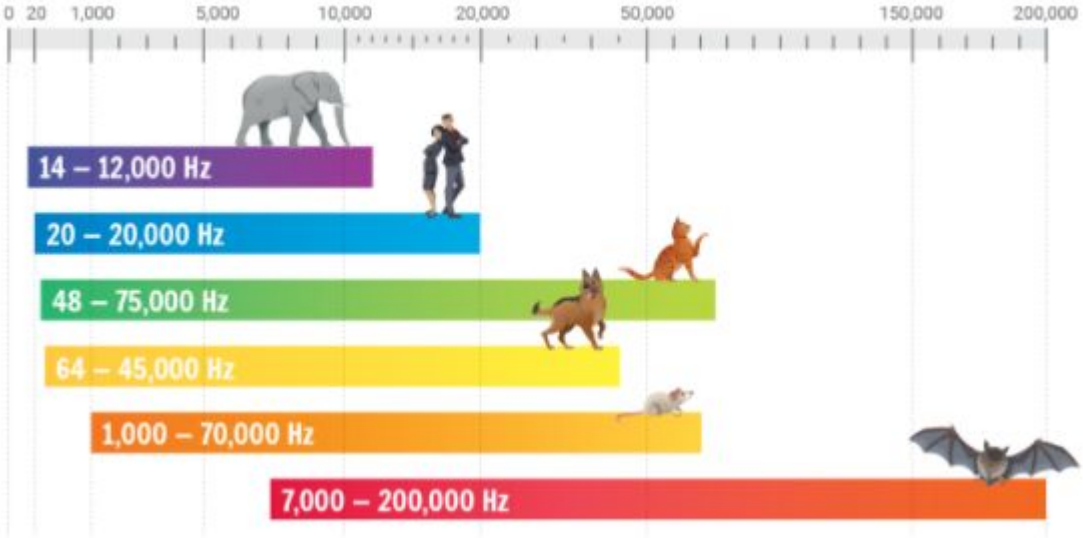
higher frequency -> higher sound

Frequency and amplitude

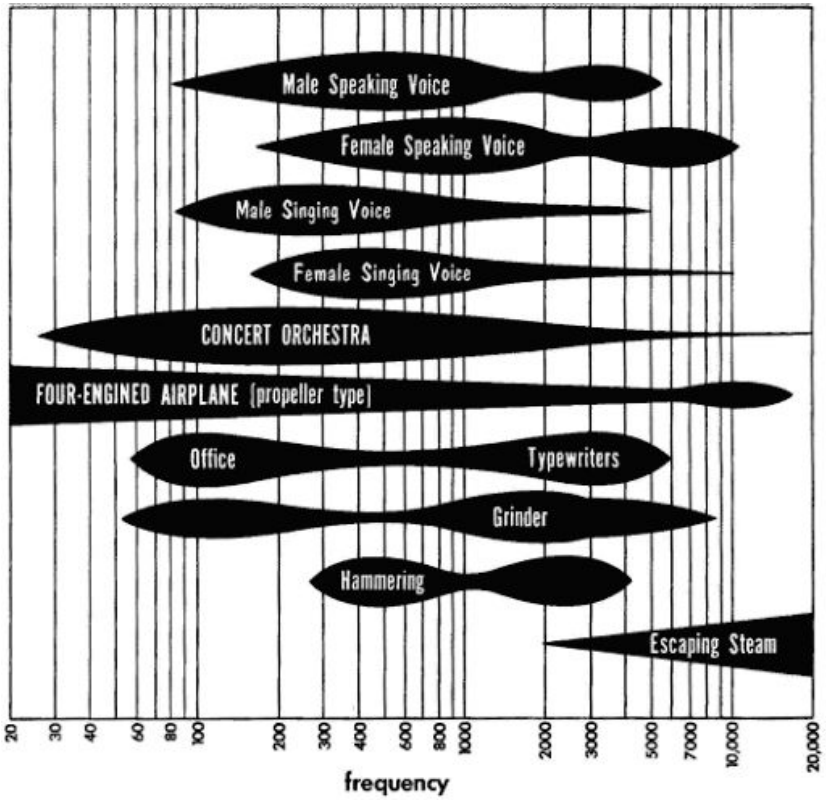


larger amplitude -> louder

Hearing range



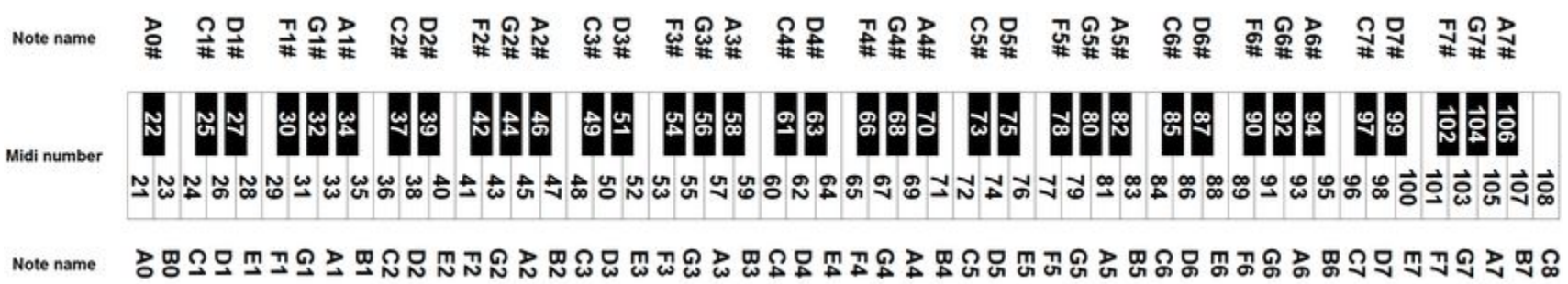
Hearing range



Pitch

- Logarithmic perception
- 2 frequencies are perceived similarly if they differ by a power of 2

Midi notes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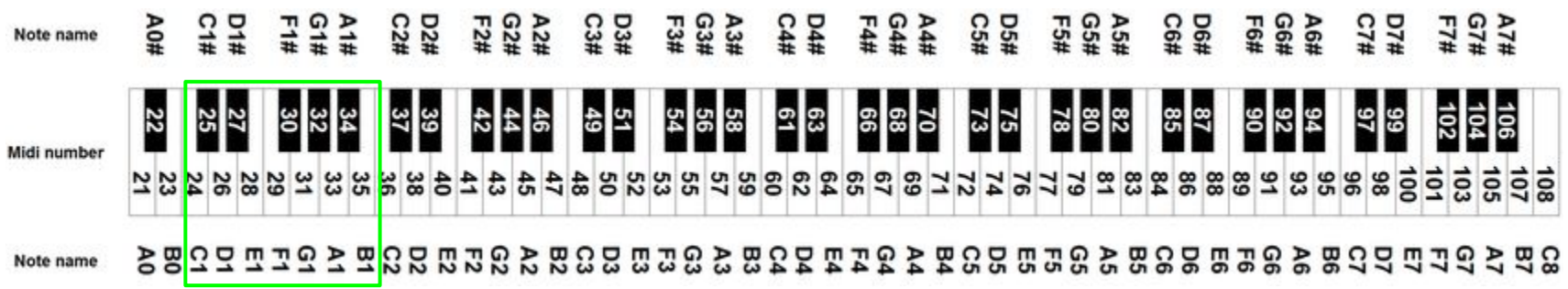
Midi number
Note name
A0# 22
A0 21
B0 23
C1 24
C1# 25
D1 26
D1# 27
E1 28
F1 29
F1# 30
G1 31
G1# 32
A1 33
A1# 34
B1 35
C2 36
C2# 37
D2 38
D2# 39
E2 40
F2 41
F2# 42
G2 43
G2# 44
A2 45
A2# 46
B2 47
C3 48
C3# 49
D3 50
D3# 51
E3 52
F3 53
F3# 54
G3 55
G3# 56
A3 57
A3# 58
B3 59
C4 60
C4# 61
D4 62
D4# 63
E4 64
F4 65
F4# 66
G4 67
G4# 68
A4 69
A4# 70
B4 71
C5 72
C5# 73
D5 74
D5# 75
E5 76
F5 77
F5# 78
G5 79
G5# 80
A5 81
A5# 82
B5 83
C6 84
C6# 85
D6 86
D6# 87
E6 88
F6 89
F6# 90
G6 91
G6# 92
A6 93
A6# 94
B6 95
C7 96
C7# 97
D7 98
D7# 99
E7 100
F7 101
F7# 102
G7 103
G7# 104
A7 105
A7# 106
C8 108
B7 107

Midi notes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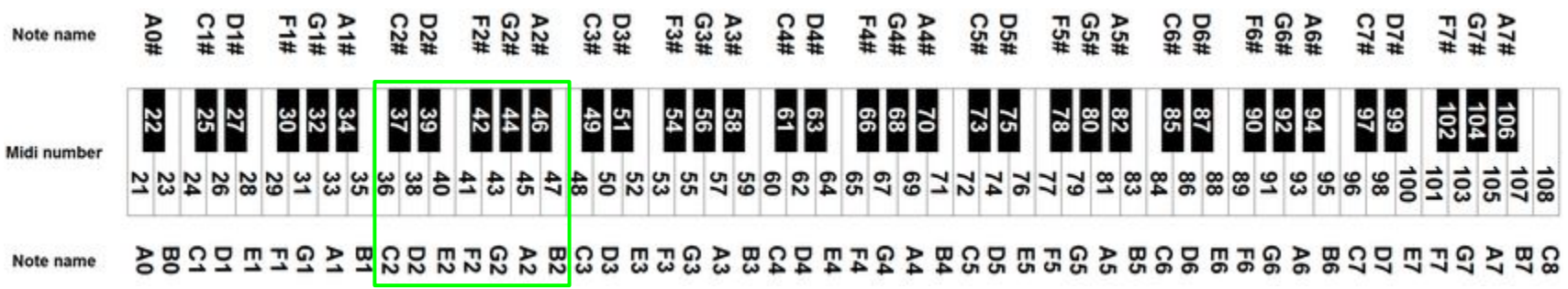
Midi number
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108
Note name
A0 B0 C1 D1 E1 F1 G1 A1 B1 C2 D2 E2 F2 G2 A2 B2 C3 D3 E3 F3 G3 A3 B3 C4 D4 E4 F4 G4 A4 B4 C5 D5 E5 F5 G5 A5 B5 C6 D6 E6 F6 G6 A6 B6 C7 D7 E7 F7 G7 A7 B7 C8

Midi notes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C1# D1# D2# D3# D4# D5# D6# D7#
F1# G1# G2# G3# G4# G5# G6# G7#
Midi number
22 34 46 58 70 82 94 106
25 27 39 51 63 75 87 99
30 32 44 56 68 80 92 104
21 23 24 26 28 29 31 33 35 36 38 40 41 43 45 47 48 50 52 53 55 57 59 60 62 64 65 67 69 71 72 74 76 77 79 81 83 84 86 88 89 91 93 95 96 98 100 101 103 105 107 108
Note name
A0 B0 C1 D1 E1 F1 G1 A1 B1 C2 D2 E2 F2 G2 A2 B2 C3 D3 E3 F3 G3 A3 B3 C4 D4 E4 F4 G4 A4 B4 C5 D5 E5 F5 G5 A5 B5 C6 D6 E6 F6 G6 A6 B6 C7 D7 E7 F7 G7 A7 C8

Midi notes


Note name
A0# A1# A2# A3# A4# A5# A6# A7#
C1# D1# D2# D3# D4# D5# D6# D7#
F1# G1# G2# G3# G4# G5# G6# G7#
Midi number
22 34 46 58 70 82 94 106
25 27 39 51 63 75 87 99
30 32 44 56 68 80 92 104
102
21 23 24 26 28 29 31 33 35 36 37 38 40 41 42 43 45 47 48 49 50 52 53 54 55 57 59 60 61 62 64 65 66 67 69 71 72 73 74 76 77 78 79 81 83 84 85 86 88 89 90 91 93 95 96 97 98 100 101 103 105 107 108
Note name
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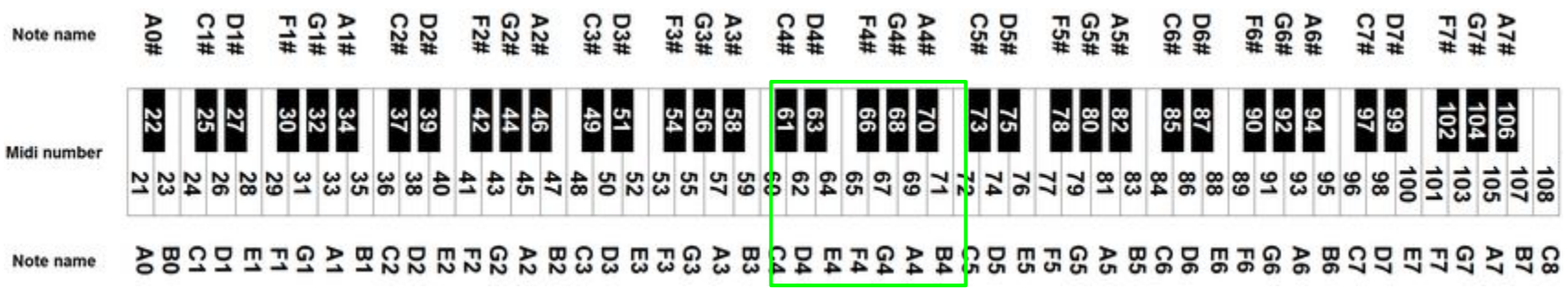
Midi notes


Note name
Midi number
Note name
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C1 C1 24
C1# D1 25
D1 D1# 26
E1 27 28
F1 F1# 29
G1 G1# 30
A1 A1# 31
B1 32 33
C2 C2# 34 35
D2 D2# 36
E2 37 38
F2 F2# 39 40
G2 G2# 41
A2 A2# 42 43
B2 44 45
C3 C3# 46 47
D3 D3# 48
E3 49 50
F3 F3# 51 52
G3 G3# 53
A3 A3# 54 55
B3 56 57
C4 C4# 58 59
D4 D4# 60
E4 61 62
F4 F4# 63 64
G4 G4# 65 66
A4 A4# 67 68
B4 69 70
C5 71 72
D5 C5# 73 74
E5 75 76
F5 F5# 77 78
G5 G5# 79 80
A5 A5# 81 82
B5 83
C6 C6# 84 85
D6 D6# 86 87
E6 88
F6 F6# 89 90
G6 G6# 91 92
A6 A6# 93 94
B6 95
C7 C7# 96 97
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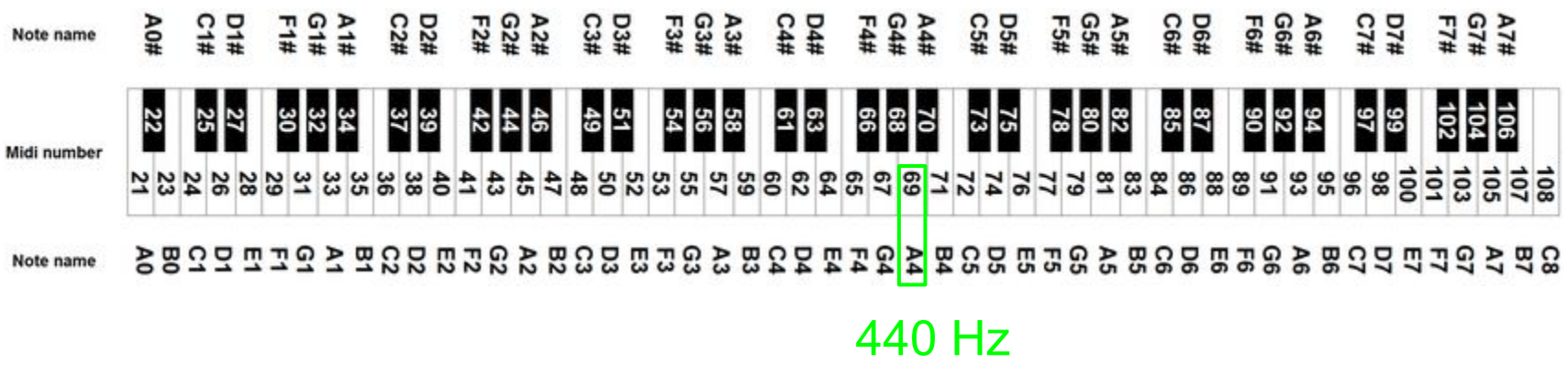
E7 100
F7 F7# 101 102
G7 G7# 103 104
A7 A7# 105 106
C8 B7 107 108

Midi notes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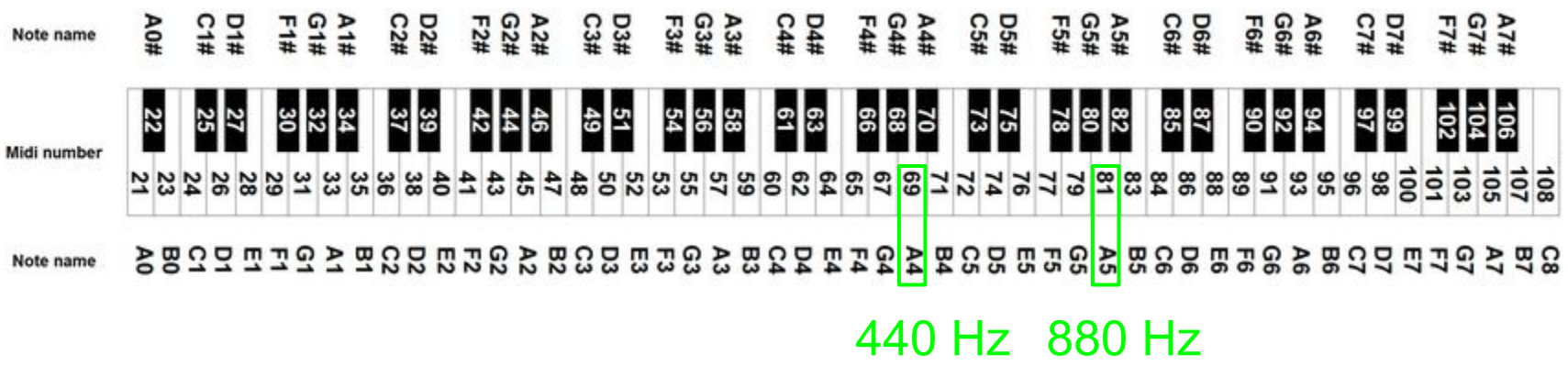
C1# D1# F1# G1# C2# D2# F2# G2# C3# D3# F3# G3# C4# D4# F4# G4# C5# D5# F5# G5# C6# D6# F6# G6# C7# D7# F7# G7#
Midi number
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108
Note name
A0 B0 C1 D1 E1 F1 G1 A1 B1 C2 D2 E2 F2 G2 A2 B2 C3 D3 E3 F3 G3 A3 B3 C4 D4 E4 F4 G4 A4 B4 C5 D5 E5 F5 G5 A5 B5 C6 D6 E6 F6 G6 A6 B6 C7 D7 E7 F7 G7 A7 C8
440 Hz

Midi notes


Note name
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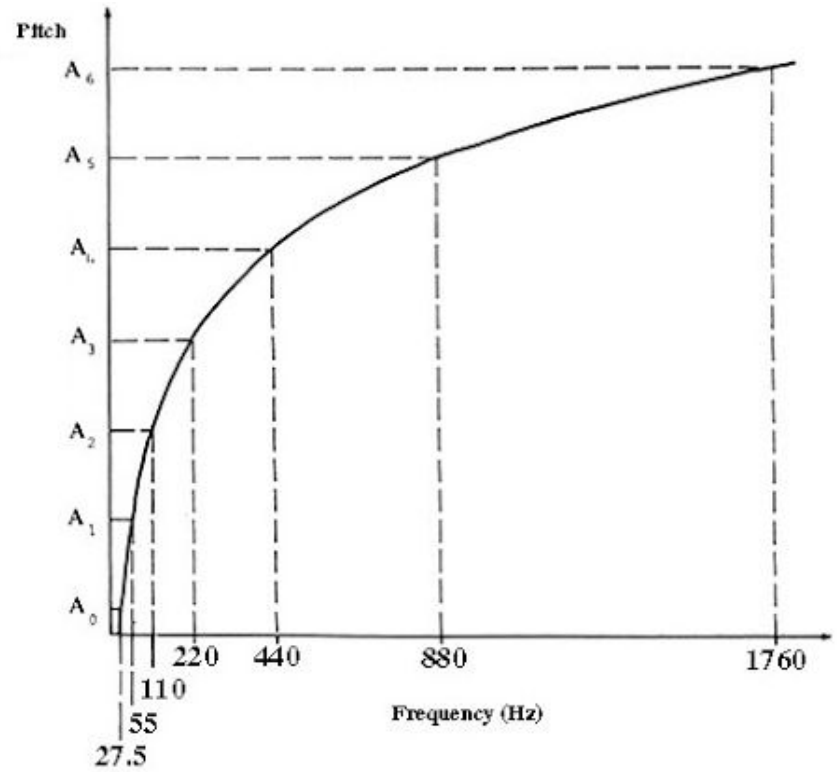
G1# G2# G3# G4# G5# G6# G7#
F1# F2# F3# F4# F5# F6# F7#
D1# D2# D3# D4# D5# D6# D7#
C1# C2# C3# C4# C5# C6# C7#
Midi number
22 25 27 30 32 34 37 39 42 44 46 49 51 54 56 58 61 63 66 68 70 73 75 78 80 82 85 87 90 92 94 97 99 102 104 106
21 23 24 26 28 29 31 33 35 36 38 40 41 43 45 47 48 50 52 53 55 57 59 60 62 64 65 67 69 71 72 74 76 77 79 81 83 84 86 88 89 91 93 95 96 98 100 101 103 105 107 108
Note name
A0 B0 C1 D1 E1 F1 G1 A1 B1 C2 D2 E2 F2 G2 A3 B3 C4 D4 E4 F4 G4 A4 B4 C5 D5 E5 F5 G5 A5 B5 C6 D6 E6 F6 G6 A6 B6 C7 D7 E7 F7 G7 A7 C8
440 Hz
880 Hz

Pitch-frequency chart



Mapping pitch to frequency

$$F(p) = 2^{\frac{p-69}{12}} \cdot 440$$

Mapping pitch to frequency

$$F(60) = 2^{\frac{60-69}{12}} \cdot 440 = 261.6$$

Mapping pitch to frequency

$$F(p+1)/F(p) = 2^{1/12} = 1.059$$

Cents

- Octave divided in 1200 cents
- 100 cents in a semitone
- Noticeable pitch difference: 10-25 cents

What’s up next?

- Intensity, power, loudness
- Timbre

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thesoundofai.slack.com