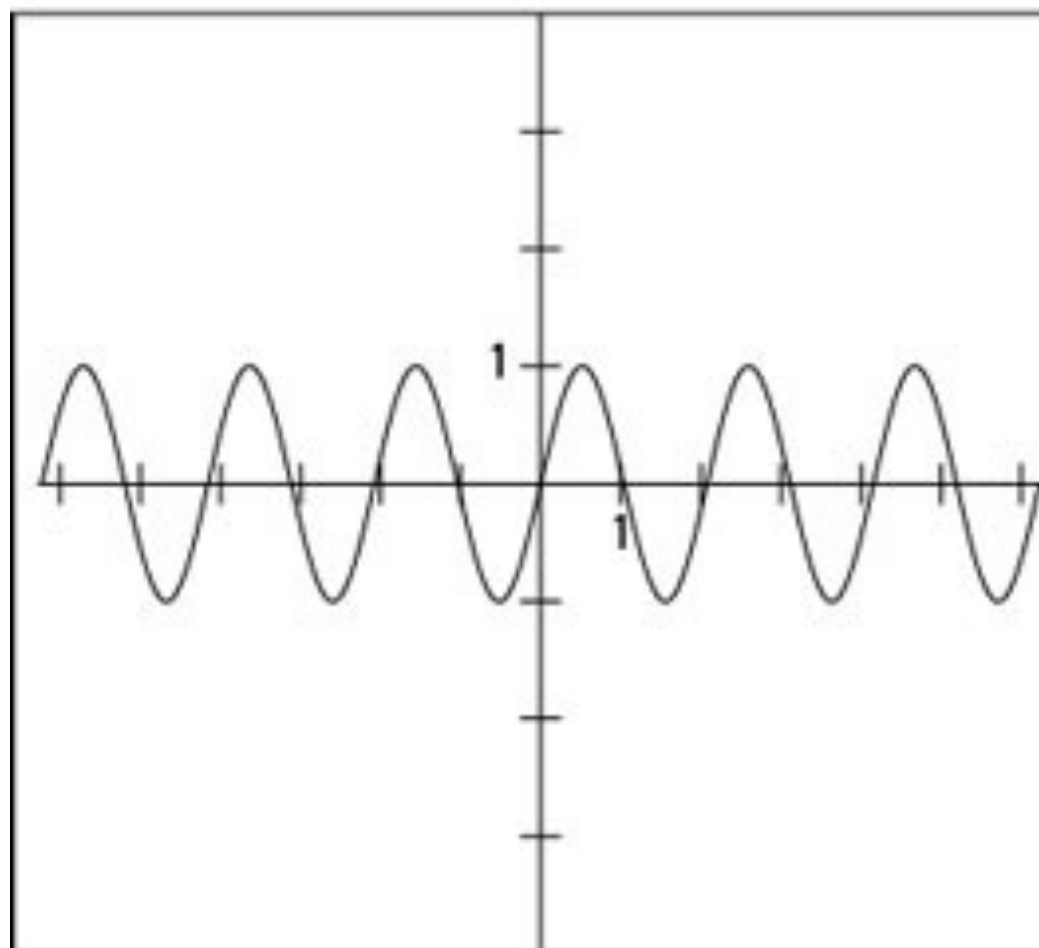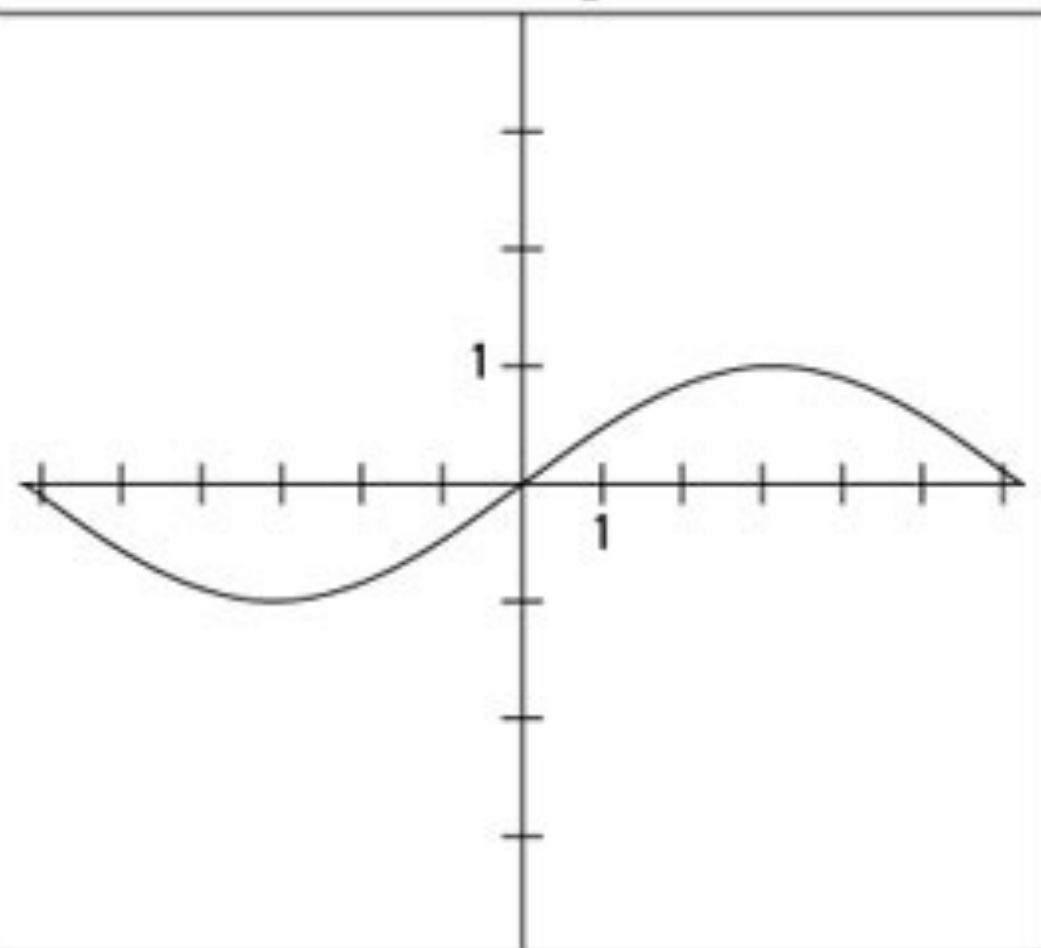$$y = \sin 3x$$

$$y = \sin \tfrac{1}{2}x$$

Linear PCM

Most common uncompressed digital audio data format.

PCM data is created by measuring an analog (real world) audio signal's magnitude at regular intervals (the sampling rate) and converting each sample to a numerical value.

CD audio uses a sampling rate of 44.1 kHz, with a 16-bit integer describing each sample—constituting the resolution or bit depth.

Sample : single numerical value for a single channel.

Frame : collection of time-coincident samples. For instance, a stereo sound file has two samples per frame, one for the left channel and one for the right channel.

In linear PCM audio, a sample value varies linearly with the amplitude of the original signal that it represents. For example, the 16-bit integer samples in standard CD audio allow 65,536 possible values between silence and maximum level. The difference in amplitude from one digital value to the next is always the same.
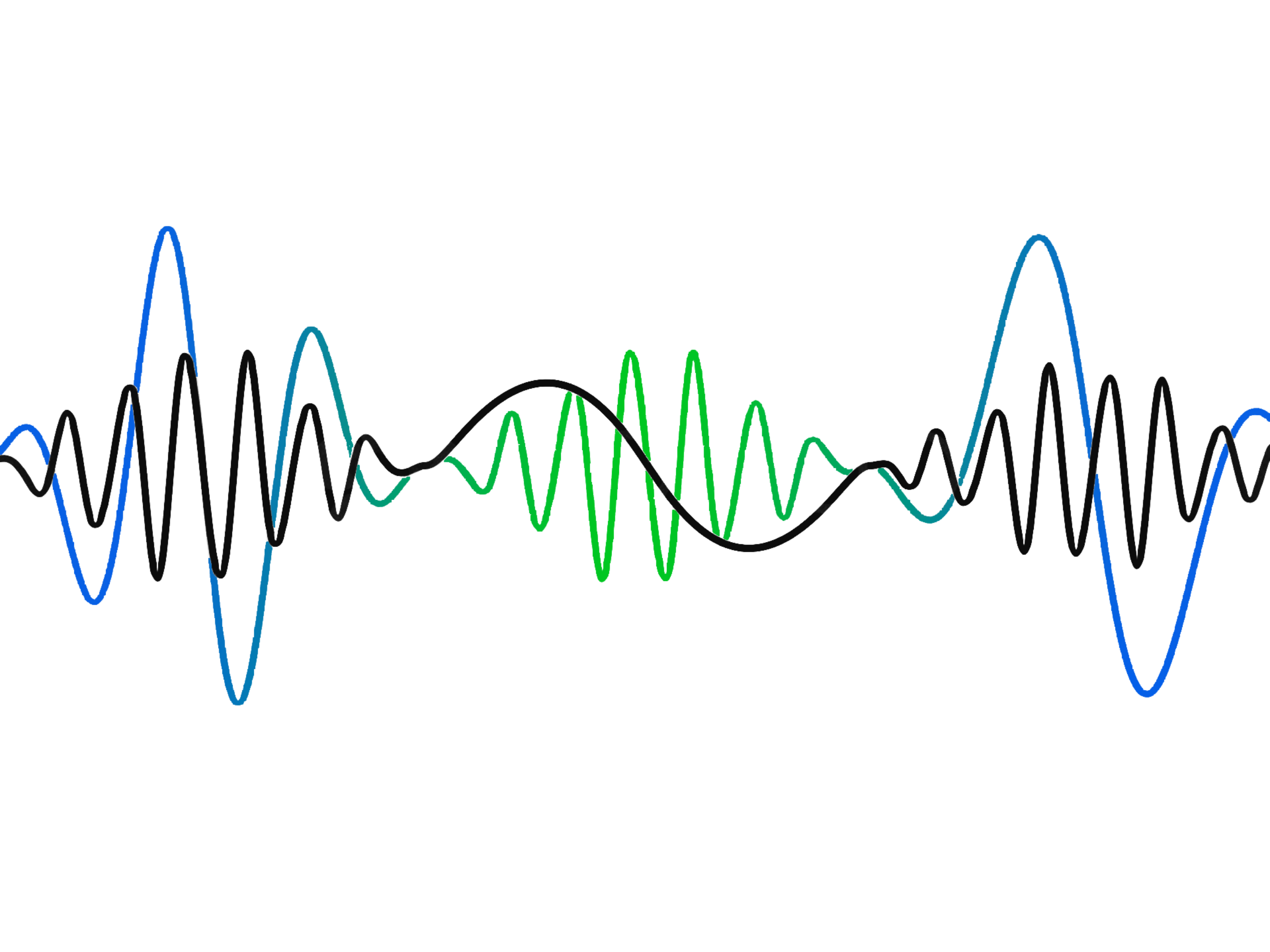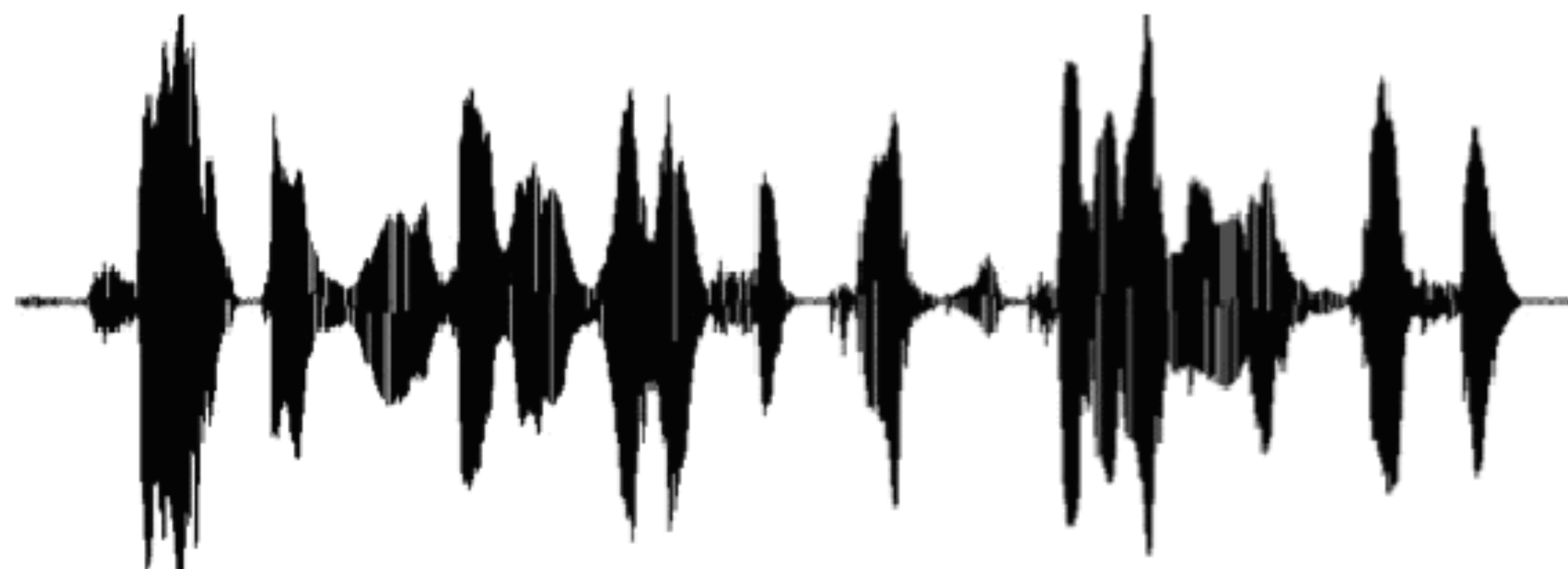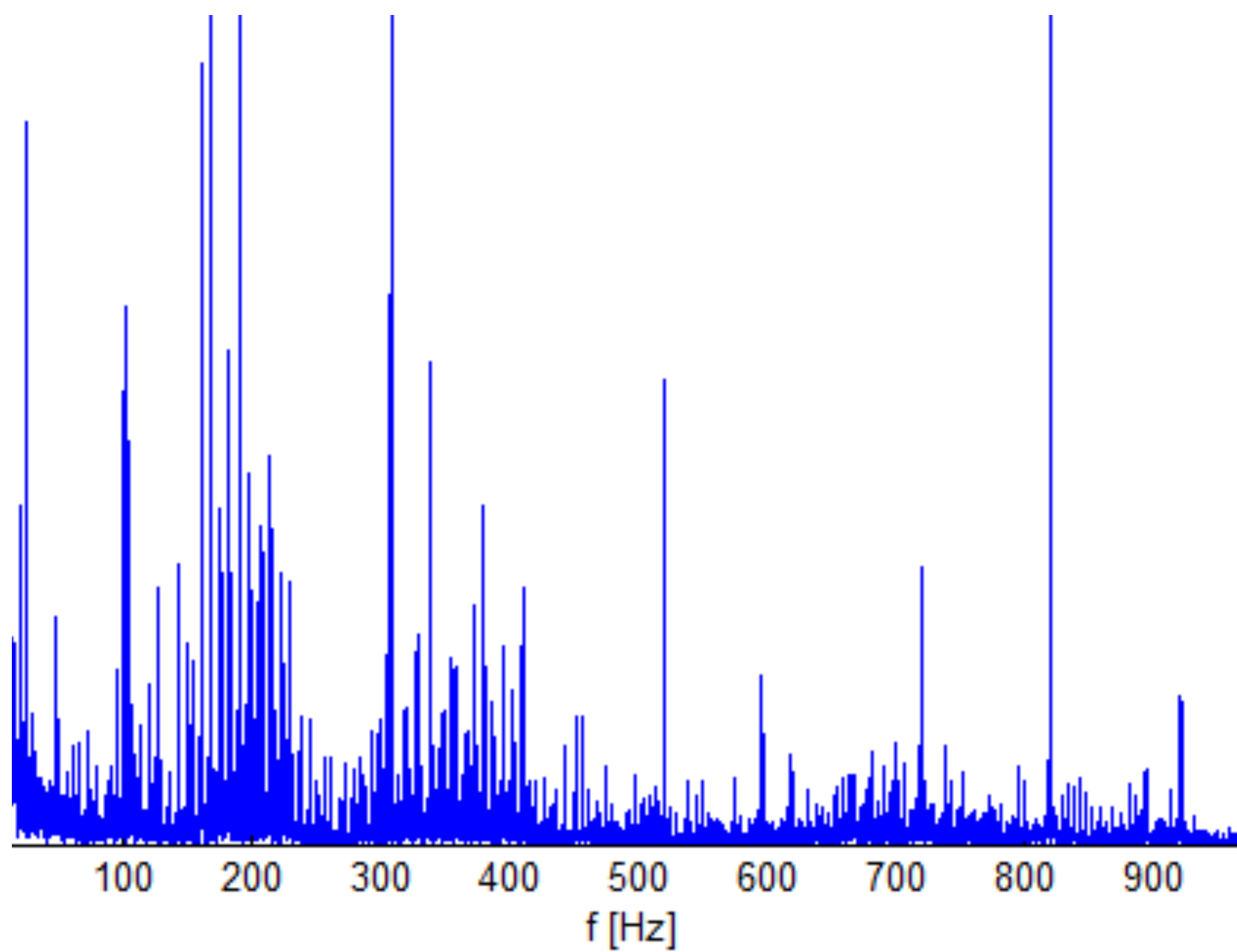
Fourier Transforms

time domain -> frequency domain

$O(n^2)$

n = # samples/render = 512

512 * 512 = 262,144 ops/render

DFT Equation

$$X(K) = \sum_{n=0}^{N-1} x(n) \cdot W_N^{nk}, \text{ where } W_N^{nk} = \exp(2\pi i nk/N)$$

$$= \sum_{n=0}^{N/2-1} \left[x(n) + (-1)^K \cdot x(n + N/2) \right] W_N^{nk}$$

Here, N is FFT size, k is from 0 to N-1

Fast Fourier Transforms

time domain -> frequency domain

O(n log n)

n = # samples/render = 512

512 * log(512) = 1,387 ops/render

$$n = \text{\# samples/sec} = 44100$$

Fourier Transforms	FFTs
$O(n^2)$	$O(n \log n)$
44100 * 44100	44100 * log(44100)
=	=
1,944,810,000 ops/sec	**204,820 ops/sec**

C   C#   D   D#   E   F   F#   G   G#   A   A#   B   C

SEMITONE >	0	1	2	3	4	5	6	7	8	9	10	11	12
NOTE >	A	Bb	B	C	Db	D	Eb	E	F	F#	G	Ab	A
FREQ.	14080	14917	15804	16744	17739	18794	19912	21096	22350	23679	25087	26579	28159
INCH	0.96	0.91	0.86	0.81	0.76	0.72	0.68	0.64	0.61	0.57	0.54	0.51	0.48
PERIOD	71 usec	67 usec	66.3 usec	59.7 usec	56.3 usec	53.2 usec	50.2 usec	47.4 usec	44.7 usec	42.2 usec	39.9 usec	37.6 usec	35.5 usec
FREQ.	7040	7459	7902	8372	8870	9397	9956	10548	11175	11840	12544	13290	14080
INCH	1.93	1.82	1.72	1.62	1.53	1.44	1.36	1.29	1.21	1.15	1.08	1.02	0.96
PERIOD	142 usec	134 usec	126 usec	119 usec	113 usec	106 usec	100 usec	94.8 usec	89.4 usec	84.5 usec	79.7 usec	75.2 usec	71 usec
FREQ.	3520	3729	3951	4186 (C8)	4435	4699	4978	5274	5588	5920	6272	6645	7040
INCH	3.85	3.64	3.43	3.24	3.06	2.89	2.72	2.57	2.43	2.29	2.16	2.04	1.93
PERIOD	284 usec	268 usec	253 usec	239 usec	225 usec	213 usec	201 usec	190 usec	179 usec	169 usec	159 usec	150 usec	142 usec
FREQ.	1760	1865	1976	2093 C7)	2217	2349	2489	2637	2794	2960	3136	3322	3520
INCH	7.70	7.27	6.86	6.48	6.12	5.77	5.45	5.14	4.85	4.58	4.32	4.08	3.85
FEET	0.64	0.61	0.57	0.54	0.51	0.48	0.45	0.43	0.40	0.38	0.36	0.34	0.32
PERIOD	568 usec	536 usec	506 usec	477 usec	451 usec	426 usec	402 usec	379 usec	358 usec	338 usec	319 usec	301 usec	284 usec
FREQ.	880	932	988	1047 (C6)	1109	1175	1245	1319	1397	1480	1568	1661	1760
INCH	15.41	14.54	13.73	12.96	12.23	11.54	10.90	10.28	9.71	9.16	8.65	8.16	7.70
FEET	1.28	1.21	1.14	1.08	1.02	0.96	0.91	0.86	0.81	0.76	0.72	0.68	0.64
PERIOD	1.14 msec	1.07 msec	1.01 msec	955 usec	901 usec	851 usec	803 usec	758 usec	715 usec	676 usec	638 usec	602 usec	568 usec
FREQ.	440	466	494	523 (C5)	554	587	622	659	698	740	784	831	880
INCH	30.82	29.09	27.46	25.91	24.46	23.09	21.79	20.57	19.41	18.32	17.30	16.33	15.41
FEET	2.57	2.42	2.29	2.16	2.04	1.92	1.82	1.71	1.62	1.53	1.44	1.36	1.28
PERIOD	2.27 msec	2.1 msec	2 msec	1.9 msec	1.8 msec	1.7 msec	1.6 msec	1.5 msec	1.4 msec	1.35 msec	1.28 msec	1.2 msec	1.14 msec

Questions?