In [ ]:
```
from thinkdsp import *
import numpy as np
import matplotlib.pyplot as plt
```

Лабораторная работа 6

Упражнение 6.1

> В этой главе утверждается, что `analyze1` требует времени пропорционально n^3, а `analyze2` - пропорционально n^2. Убедитесь в этом, запуская их с несколькими разными массивами и засекая время работы. Используйте команду %timeit

In [ ]:
```
from thinkdsp import UncorrelatedGaussianNoise

signal = UncorrelatedGaussianNoise()
noise = signal.make_wave(duration=1.0, framerate=16384)
```

Начнем с генерации сигнала белого шума

In [ ]:
```
PI2 = np.pi * 2

def analyze1(ys, fs, ts):
    args = np.outer(ts, fs)
    M = np.cos(PI2 * args)
    amps = np.linalg.solve(M, ys)
    return amps
```

In [ ]:
```
from scipy.stats import linregress

loglog = dict(xscale='log', yscale='log')

def plot_bests(ns, bests):
    plt.plot(ns, bests)
    decorate(**loglog)

    x = np.log(ns)
    y = np.log(bests)
    t = linregress(x,y)
    slope = t[0]

    return slope
```

Фукнкция для построения графика в логарифмическом масштабе и вычисления коэффициента наклона построеной прямой

In [ ]:
```
def run_speed_test(ns, func):
    results = []
    for N in ns:
        print(N)
        ts = (0.5 + np.arange(N)) / N
        freqs = (0.5 + np.arange(N)) / 2
        ys = noise.ys[:N]
        result = %timeit -r1 -o func(ys, freqs, ts)
        results.append(result)
```

```
    bests = [result.best for result in results]
    return bests
```

Функция для замера времени работы функции вычисления амплитуд.

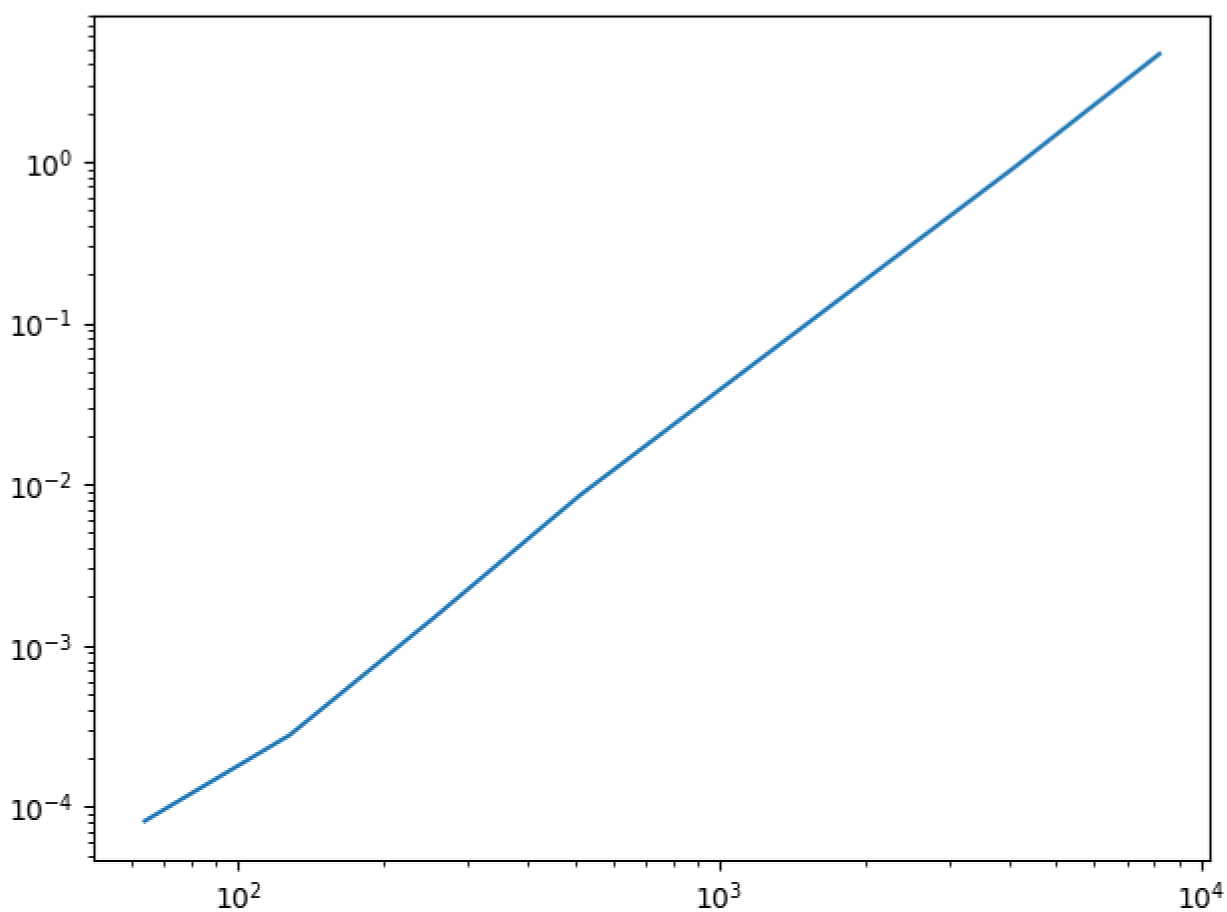
In [ ]:
```
ns = 2 ** np.arange(6, 14)
ns
```

Out[ ]:
```
array([  64,  128,  256,  512, 1024, 2048, 4096, 8192], dtype=int32)
```

In [ ]:
```
bests = run_speed_test(ns, analyze1)
plot_bests(ns, bests)
```

```
64
81.5 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 10,000 loops each)
128
278 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 1,000 loops each)
256
1.5 ms ± 0 ns per loop (mean ± std. dev. of 1 run, 1,000 loops each)
512
8.52 ms ± 0 ns per loop (mean ± std. dev. of 1 run, 100 loops each)
1024
40.7 ms ± 0 ns per loop (mean ± std. dev. of 1 run, 10 loops each)
2048
194 ms ± 0 ns per loop (mean ± std. dev. of 1 run, 10 loops each)
4096
923 ms ± 0 ns per loop (mean ± std. dev. of 1 run, 1 loop each)
8192
4.65 s ± 0 ns per loop (mean ± std. dev. of 1 run, 1 loop each)
```

Out[ ]:
```
2.2903340406224615
```



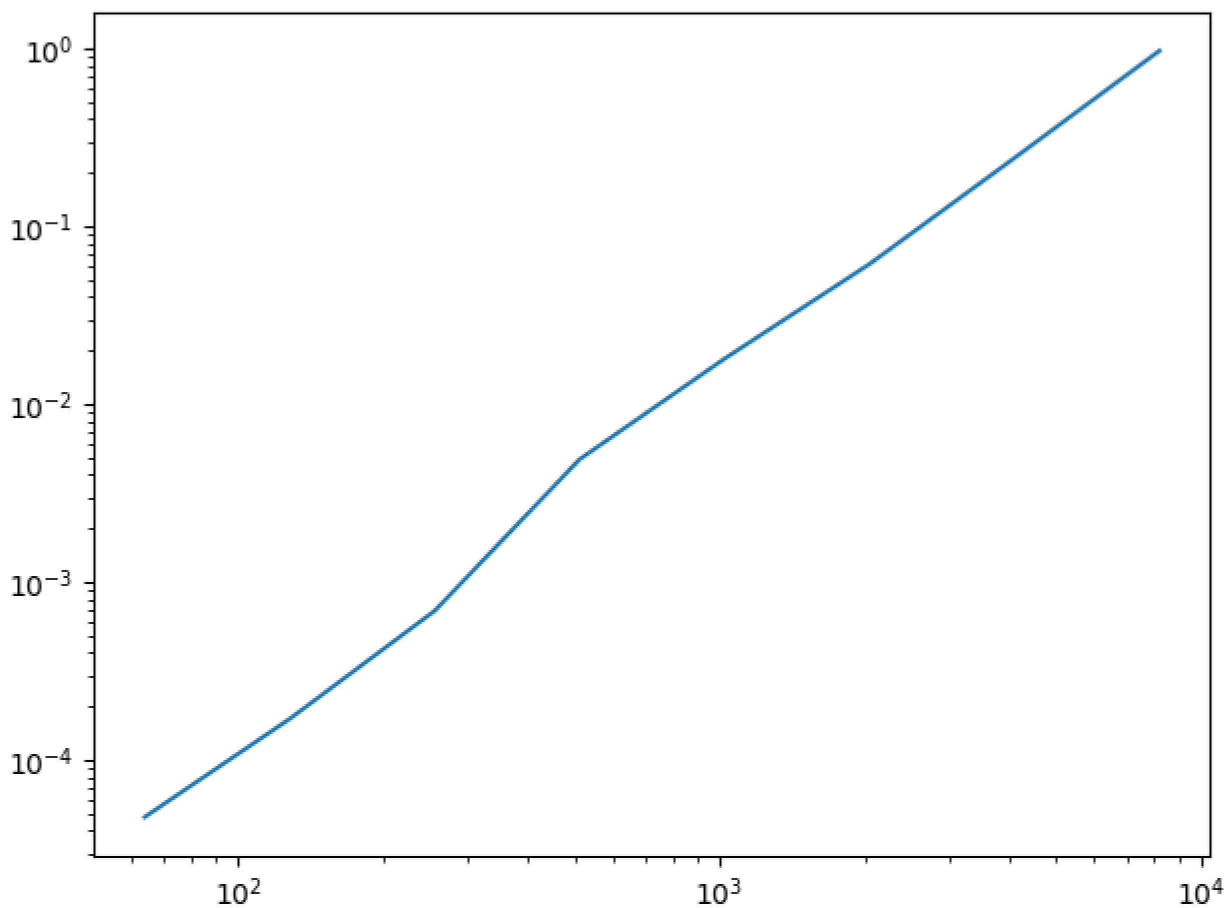
По итогам тестирования `analyze1` получили коэффициент наклона равный 2.3, а ожидали 3. Это может быть связано с тем, что на малых размерах массивов сложность равна n^2

In [ ]:
```
def analyze2(ys, fs, ts):
    args = np.outer(ts, fs)
    M = np.cos(PI2 * args)
    amps = np.dot(M, ys) / 2
    return amps
```

In [ ]:
```
bests2 = run_speed_test(ns, analyze2)
plot_bests(ns, bests2)
```

```
64
47.9 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 10,000 loops each)
128
171 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 10,000 loops each)
256
690 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 1,000 loops each)
512
4.9 ms ± 0 ns per loop (mean ± std. dev. of 1 run, 100 loops each)
1024
18 ms ± 0 ns per loop (mean ± std. dev. of 1 run, 10 loops each)
2048
61.4 ms ± 0 ns per loop (mean ± std. dev. of 1 run, 10 loops each)
4096
242 ms ± 0 ns per loop (mean ± std. dev. of 1 run, 1 loop each)
8192
971 ms ± 0 ns per loop (mean ± std. dev. of 1 run, 1 loop each)
```

Out[ ]:
```
2.0691057950467195
```



Результаты для `analyze2` образуют почти прямую линию с коэффициентом наклона 2

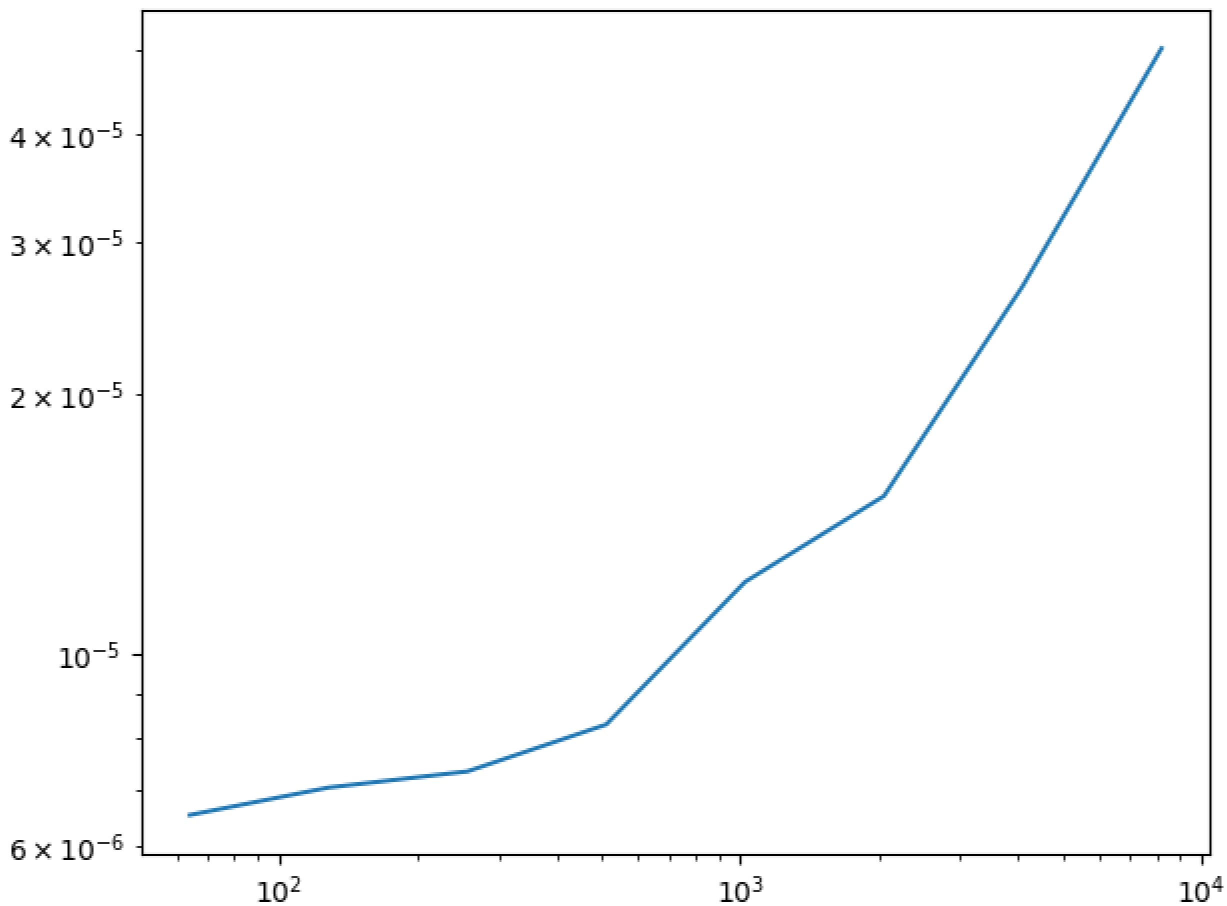
In [ ]:
```
import scipy.fftpack

def scipy_dct(ys, freqs, ts):
    return scipy.fftpack.dct(ys, type=3)
```

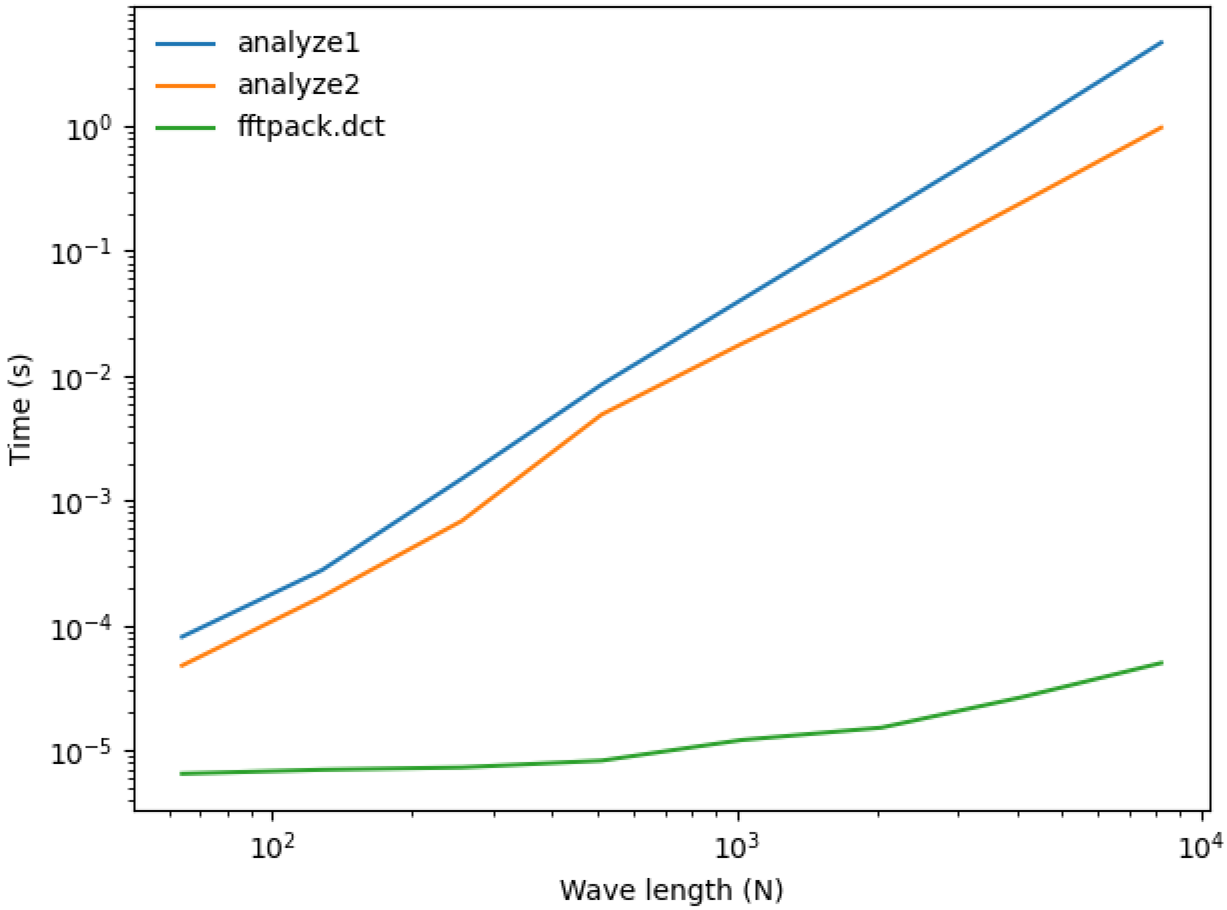
In [ ]:
```
bests3 = run_speed_test(ns, scipy_dct)
plot_bests(ns, bests3)
```

```
64
6.53 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 100,000 loops each)
128
7.03 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 100,000 loops each)
256
7.34 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 100,000 loops each)
512
8.31 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 100,000 loops each)
1024
12.1 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 100,000 loops each)
2048
15.3 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 100,000 loops each)
4096
26.7 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 10,000 loops each)
8192
50.3 µs ± 0 ns per loop (mean ± std. dev. of 1 run, 10,000 loops each)
```

Out[ ]:
```
0.40423522550639285
```



In [ ]:
```
plt.plot(ns, bests, label='analyze1')
plt.plot(ns, bests2, label='analyze2')
plt.plot(ns, bests3, label='fftpack.dct')
decorate(xlabel='Wave length (N)', ylabel='Time (s)', **loglog)
```



Упражнение 6.2

> Одно из основных применений ДКП - это сжатие звука и изображений. В простейшей форме ДКП при сжатии работает следующим образом:
>
> 1. Разбивает длинный сигнал на сегменты
> 2. Вычисляет ДКП каждого сегмента
> 3. Определяет частотные компоненты с такой амплитудой, что их не слышно, и удаляет их, сохраняя только оставшиеся частоты и амплитуды.
> 4. При воспроизведении сигнала загружает частоты и амплитуды каждого сегмента и применяет обратное ДКП
>
> Реализуйте версию этого алгоритма и примените его для записи музыки или речи. Сколько компонент можно удалить до того, как разнрица станет заметной?
> Для того, чтобы этот метод стал практичным, нужен способ хранения прореженного массива, то есть массива, где большинство элементов равно нулю

In [ ]:
```
from thinkdsp import read_wave

wave = read_wave('100475__iluppai__saxophone-weep.wav')
wave.make_audio()
```

Out[ ]: 0:00 / 0:11

In [ ]:
```
segment = wave.segment(start=1, duration=0.5)
segment.normalize()
```

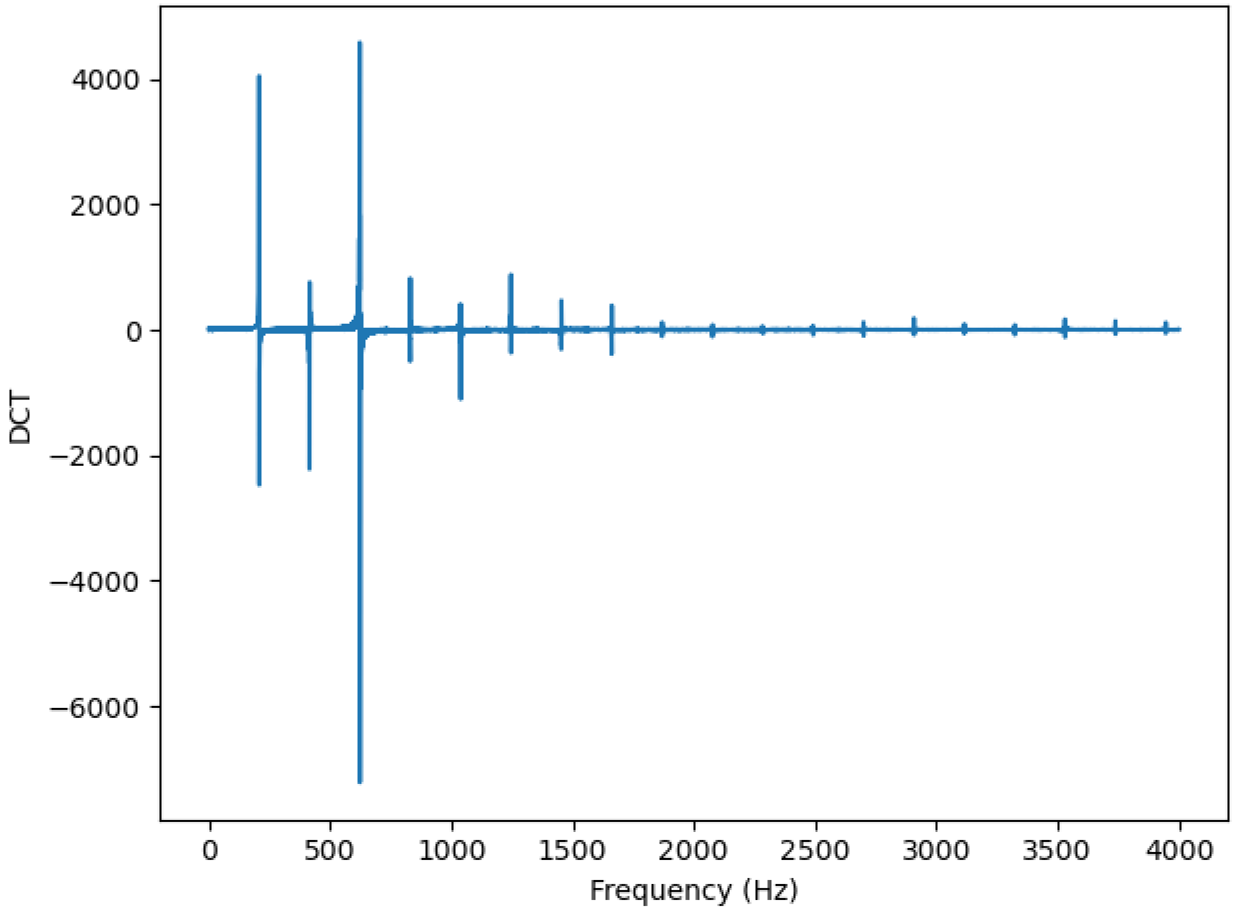
```
segment.make_audio()
```

Out[ ]:

0:00 / 0:00

In [ ]:

```
seg_dct = segment.make_dct()
seg_dct.plot(high=4000)
decorate(xlabel='Frequency (Hz)', ylabel='DCT')
```



В сегменте только несколько компонент с достаточно большой амплитудой, а остальные компоненты близки к нулю. Будем убирать эти компоненты.

In [ ]:

```
def compress(dct, thresh=1):
    count = 0
    for i, amp in enumerate(dct.amps):
        if np.abs(amp) < thresh:
            dct.hs[i] = 0
            count += 1

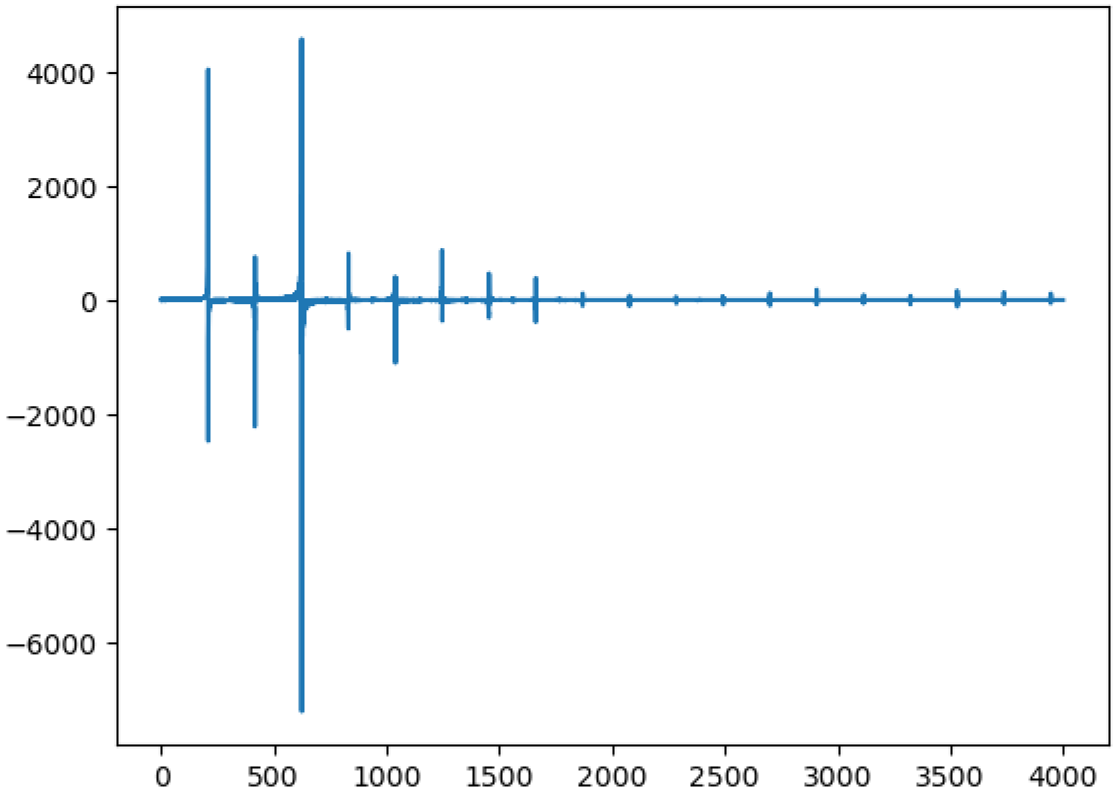
    n = len(dct.amps)
    print(count, n, 100 * count / n, sep='\t')
```

Функция `compress` делает равными нулю компоненты, меньшие предельного значения амплитуды. Она выводит количество обнуленных компонент и все число элементов.

In [ ]:

```
compress(seg_dct, thresh=10)
seg_dct.plot(high=4000)
```

```
20292	22050	92.02721088435374
```



Как мы видим было обнулено 92% всех компонент.

In [ ]:
```
seg2 = seg_dct.make_wave()
seg2.make_audio()
```

Out[ ]:

0:00 / 0:00

И звук сегмента не изменился

In [ ]:
```
from thinkdsp import Spectrogram

def make_dct_spectrogram(wave, seg_length):
    window = np.hamming(seg_length)
    i, j = 0, seg_length
    step = seg_length // 2

    # map from time to Spectrum
    spec_map = {}

    while j < len(wave.ys):
        segment = wave.slice(i, j)
        segment.window(window)

        # the nominal time for this segment is the midpoint
        t = (segment.start + segment.end) / 2
        spec_map[t] = segment.make_dct()

        i += step
        j += step

    return Spectrogram(spec_map, seg_length)
```

Функция для вычисления спектрограммы с использованием ДКТ. Затем мы можем применить фунцию сжатия к каждому сенменту спектрограммы.

In [ ]:
```
spectro = make_dct_spectrogram(wave, seg_length=1024)
for t, dct in sorted(spectro.spec_map.items()):
    compress(dct, thresh=0.2)
```

1018	1024	99.4140625
1016	1024	99.21875
1014	1024	99.0234375
1017	1024	99.31640625
1016	1024	99.21875
1017	1024	99.31640625
1016	1024	99.21875
1020	1024	99.609375
1014	1024	99.0234375
1005	1024	98.14453125
1009	1024	98.53515625
1015	1024	99.12109375
1015	1024	99.12109375
1016	1024	99.21875
1016	1024	99.21875
1015	1024	99.12109375
1017	1024	99.31640625
1020	1024	99.609375
1013	1024	98.92578125
1017	1024	99.31640625
1013	1024	98.92578125
1017	1024	99.31640625
1018	1024	99.4140625
1015	1024	99.12109375
1013	1024	98.92578125
794	1024	77.5390625
785	1024	76.66015625
955	1024	93.26171875
995	1024	97.16796875
992	1024	96.875
976	1024	95.3125
925	1024	90.33203125
802	1024	78.3203125
836	1024	81.640625
850	1024	83.0078125
882	1024	86.1328125
883	1024	86.23046875
891	1024	87.01171875
901	1024	87.98828125
902	1024	88.0859375
900	1024	87.890625
900	1024	87.890625
894	1024	87.3046875
904	1024	88.28125
901	1024	87.98828125
915	1024	89.35546875
913	1024	89.16015625
899	1024	87.79296875
905	1024	88.37890625
905	1024	88.37890625
888	1024	86.71875
898	1024	87.6953125
879	1024	85.83984375
893	1024	87.20703125
893	1024	87.20703125
882	1024	86.1328125
874	1024	85.3515625
876	1024	85.546875
864	1024	84.375
879	1024	85.83984375
869	1024	84.86328125
872	1024	85.15625
871	1024	85.05859375
878	1024	85.7421875

872	1024	85.15625
859	1024	83.88671875
879	1024	85.83984375
889	1024	86.81640625
872	1024	85.15625
837	1024	81.73828125
842	1024	82.2265625
825	1024	80.56640625
839	1024	81.93359375
796	1024	77.734375
792	1024	77.34375
769	1024	75.09765625
836	1024	81.640625
919	1024	89.74609375
913	1024	89.16015625
942	1024	91.9921875
837	1024	81.73828125
739	1024	72.16796875
737	1024	71.97265625
726	1024	70.8984375
728	1024	71.09375
733	1024	71.58203125
717	1024	70.01953125
716	1024	69.921875
676	1024	66.015625
712	1024	69.53125
697	1024	68.06640625
718	1024	70.1171875
717	1024	70.01953125
718	1024	70.1171875
681	1024	66.50390625
707	1024	69.04296875
691	1024	67.48046875
681	1024	66.50390625
709	1024	69.23828125
684	1024	66.796875
743	1024	72.55859375
710	1024	69.3359375
712	1024	69.53125
714	1024	69.7265625
719	1024	70.21484375
708	1024	69.140625
725	1024	70.80078125
700	1024	68.359375
726	1024	70.8984375
716	1024	69.921875
725	1024	70.80078125
692	1024	67.578125
675	1024	65.91796875
747	1024	72.94921875
741	1024	72.36328125
730	1024	71.2890625
701	1024	68.45703125
721	1024	70.41015625
747	1024	72.94921875
725	1024	70.80078125
744	1024	72.65625
720	1024	70.3125
716	1024	69.921875
723	1024	70.60546875
721	1024	70.41015625
734	1024	71.6796875
730	1024	71.2890625
718	1024	70.1171875

730	1024	71.2890625
723	1024	70.60546875
749	1024	73.14453125
727	1024	70.99609375
728	1024	71.09375
746	1024	72.8515625
739	1024	72.16796875
757	1024	73.92578125
741	1024	72.36328125
751	1024	73.33984375
775	1024	75.68359375
749	1024	73.14453125
768	1024	75.0
763	1024	74.51171875
771	1024	75.29296875
758	1024	74.0234375
745	1024	72.75390625
756	1024	73.828125
744	1024	72.65625
743	1024	72.55859375
757	1024	73.92578125
779	1024	76.07421875
760	1024	74.21875
770	1024	75.1953125
759	1024	74.12109375
737	1024	71.97265625
739	1024	72.16796875
751	1024	73.33984375
762	1024	74.4140625
754	1024	73.6328125
811	1024	79.19921875
899	1024	87.79296875
832	1024	81.25
800	1024	78.125
756	1024	73.828125
748	1024	73.046875
727	1024	70.99609375
744	1024	72.65625
725	1024	70.80078125
720	1024	70.3125
755	1024	73.73046875
737	1024	71.97265625
766	1024	74.8046875
747	1024	72.94921875
743	1024	72.55859375
727	1024	70.99609375
726	1024	70.8984375
746	1024	72.8515625
764	1024	74.609375
751	1024	73.33984375
734	1024	71.6796875
741	1024	72.36328125
760	1024	74.21875
750	1024	73.2421875
784	1024	76.5625
730	1024	71.2890625
757	1024	73.92578125
761	1024	74.31640625
734	1024	71.6796875
744	1024	72.65625
757	1024	73.92578125
714	1024	69.7265625
740	1024	72.265625
738	1024	72.0703125

763	1024	74.51171875
766	1024	74.8046875
745	1024	72.75390625
751	1024	73.33984375
759	1024	74.12109375
756	1024	73.828125
756	1024	73.828125
756	1024	73.828125
755	1024	73.73046875
746	1024	72.8515625
756	1024	73.828125
738	1024	72.0703125
757	1024	73.92578125
764	1024	74.609375
765	1024	74.70703125
762	1024	74.4140625
768	1024	75.0
773	1024	75.48828125
782	1024	76.3671875
773	1024	75.48828125
766	1024	74.8046875
755	1024	73.73046875
766	1024	74.8046875
772	1024	75.390625
810	1024	79.1015625
739	1024	72.16796875
717	1024	70.01953125
722	1024	70.5078125
739	1024	72.16796875
725	1024	70.80078125
736	1024	71.875
759	1024	74.12109375
769	1024	75.09765625
749	1024	73.14453125
710	1024	69.3359375
748	1024	73.046875
720	1024	70.3125
732	1024	71.484375
721	1024	70.41015625
734	1024	71.6796875
763	1024	74.51171875
747	1024	72.94921875
754	1024	73.6328125
755	1024	73.73046875
764	1024	74.609375
801	1024	78.22265625
768	1024	75.0
780	1024	76.171875
773	1024	75.48828125
764	1024	74.609375
775	1024	75.68359375
740	1024	72.265625
794	1024	77.5390625
796	1024	77.734375
769	1024	75.09765625
751	1024	73.33984375
782	1024	76.3671875
758	1024	74.0234375
777	1024	75.87890625
794	1024	77.5390625
784	1024	76.5625
788	1024	76.953125
773	1024	75.48828125
783	1024	76.46484375

784	1024	76.5625
785	1024	76.66015625
806	1024	78.7109375
807	1024	78.80859375
797	1024	77.83203125
785	1024	76.66015625
794	1024	77.5390625
766	1024	74.8046875
790	1024	77.1484375
746	1024	72.8515625
762	1024	74.4140625
813	1024	79.39453125
801	1024	78.22265625
782	1024	76.3671875
776	1024	75.78125
755	1024	73.73046875
780	1024	76.171875
784	1024	76.5625
805	1024	78.61328125
791	1024	77.24609375
803	1024	78.41796875
799	1024	78.02734375
795	1024	77.63671875
797	1024	77.83203125
806	1024	78.7109375
781	1024	76.26953125
795	1024	77.63671875
797	1024	77.83203125
893	1024	87.20703125
775	1024	75.68359375
787	1024	76.85546875
746	1024	72.8515625
767	1024	74.90234375
749	1024	73.14453125
749	1024	73.14453125
738	1024	72.0703125
736	1024	71.875
747	1024	72.94921875
760	1024	74.21875
737	1024	71.97265625
752	1024	73.4375
756	1024	73.828125
772	1024	75.390625
740	1024	72.265625
737	1024	71.97265625
766	1024	74.8046875
791	1024	77.24609375
765	1024	74.70703125
771	1024	75.29296875
786	1024	76.7578125
770	1024	75.1953125
761	1024	74.31640625
765	1024	74.70703125
756	1024	73.828125
758	1024	74.0234375
765	1024	74.70703125
785	1024	76.66015625
769	1024	75.09765625
781	1024	76.26953125
792	1024	77.34375
798	1024	77.9296875
809	1024	79.00390625
778	1024	75.9765625
782	1024	76.3671875

776	1024	75.78125
791	1024	77.24609375
794	1024	77.5390625
783	1024	76.46484375
771	1024	75.29296875
792	1024	77.34375
785	1024	76.66015625
812	1024	79.296875
809	1024	79.00390625
799	1024	78.02734375
798	1024	77.9296875
803	1024	78.41796875
800	1024	78.125
805	1024	78.61328125
803	1024	78.41796875
799	1024	78.02734375
802	1024	78.3203125
804	1024	78.515625
809	1024	79.00390625
784	1024	76.5625
791	1024	77.24609375
814	1024	79.4921875
788	1024	76.953125
816	1024	79.6875
810	1024	79.1015625
820	1024	80.078125
823	1024	80.37109375
813	1024	79.39453125
799	1024	78.02734375
807	1024	78.80859375
799	1024	78.02734375
789	1024	77.05078125
813	1024	79.39453125
819	1024	79.98046875
809	1024	79.00390625
784	1024	76.5625
809	1024	79.00390625
810	1024	79.1015625
785	1024	76.66015625
838	1024	81.8359375
821	1024	80.17578125
822	1024	80.2734375
800	1024	78.125
815	1024	79.58984375
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813	1024	79.39453125
824	1024	80.46875
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788	1024	76.953125
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804	1024	78.515625
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812	1024	79.296875
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804	1024	78.515625
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813	1024	79.39453125
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814	1024	79.4921875
901	1024	87.98828125
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780	1024	76.171875
773	1024	75.48828125
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750	1024	73.2421875
730	1024	71.2890625
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775	1024	75.68359375
782	1024	76.3671875
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776	1024	75.78125
760	1024	74.21875
783	1024	76.46484375
744	1024	72.65625
766	1024	74.8046875
761	1024	74.31640625
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867	1024	84.66796875
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874	1024	85.3515625

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778	1024	75.9765625
767	1024	74.90234375
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846	1024	82.6171875
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981	1024	95.80078125
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1018    1024    99.4140625
1018    1024    99.4140625
```

In [ ]:

```
wave2 = spectro.make_wave()
wave2.make_audio()
```

Out[ ]:

0:00 / 0:11

Эффект сжатия заметен. При воспроизведении звука можем услышать небольшой шум

In [ ]: