Assignment #4: Profiler Reports

1. Profiler result before any changes:

3947233 function calls (3947227 primitive calls) in 809.819 seconds

```
ncalls tottime percall cumtime percall filename:lineno(function)
                  0.016 809.819 809.819 <string>:1(<module>)
       1 0.016
                           0.000
       2
           0.000
                    0.000
                                   0.000 <string>:12(__new__)
                                     0.001 _methods.py:25(_amax)
0.001 _methods.py:28(_amin)
0.000 chunk.py:117(tell)
           0.000
                    0.000
                            0.001
       1
           0.000
                    0.000
                            0.001
           0.000
                    0.000
                            0.000
                                    0.000 chunk.py:122(read)
   22/16
           0.000
                    0.000
                            0.001
          0.000
                          0.000
                                   0.000 chunk.py:145(skip)
       2
                   0.000
                          0.000 0.000 chunk.py:52(__init__)
          0.000
       6
                  0.000
          0.000
                  0.000 0.000 0.000 chunk.py:78(getname)
       6
                  0.000 0.000 0.000 chunk.py:98(seek)
       2
          0.000
          0.000
                  0.000 0.031
                                   0.016 convolve.py:18(LoadWaveFile)
       1
          0.758
                  0.758 1.129
                                   1.129 convolve.py:38(SaveWaveFile)
       1 680.948 680.948 680.948 convolve.py:49(Convolve)
       1 127.599 127.599 127.601 127.601 convolve.py:59(Normalize)
                  0.000 809.803 809.803 convolve.py:75(Main)
          0.000
       1
       1
           0.000
                   0.000
                           0.001
                                   0.001 fromnumeric.py:2174(amax)
       2
                                     0.001 fromnumeric.py:2275(amin)
           0.000
                    0.000
                            0.001
       2
           0.000
                    0.000
                            0.000
                                     0.000 wave.py:125(initfp)
           0.000
                    0.000
                             0.000
                                     0.000 wave.py:156(__init__)
       2
           0.000
                    0.000
                            0.000
                                     0.000 wave.py:169(__del_
                                   0.000 wave.py:188(close)
           0.000
                    0.000
                            0.000
       4
                                   0.000 wave.py:198(getnchannels)
           0.000
                           0.000
                    0.000
       4
          0.000
                  0.000
                          0.000
                                   0.000 wave.py:201(getnframes)
       4
       4
          0.000
                  0.000
                           0.000 0.000 wave.py:204(getsampwidth)
          0.000
                  0.000
                          0.000 0.000 wave.py:207(getframerate)
       2
          0.000
                  0.000
                          0.000 0.000 wave.py:210(getcomptype)
       2
          0.000
                  0.000
                          0.000 0.000 wave.py:213(getcompname)
                          0.000 0.000 wave.py:216(getparams)
       2
          0.000
                  0.000
          0.000
                  0.000
                          0.001
                                   0.000 wave.py:233(readframes)
       2
       2
           0.000
                  0.000
                           0.000
                                   0.000 wave.py:254(_read_fmt_chunk)
       1
           0.000
                    0.000
                            0.001
                                    0.001 wave.py:291(__init__)
       1
           0.000
                                     0.000 wave.py:303(<u>initfp</u>)
                    0.000
                            0.000
                                     0.000 wave.py:315(__del__)
           0.000
                    0.000
                            0.000
           0.000
                    0.000
                            0.000
                                     0.000 wave.py:327 (setnchannels)
       1
           0.000
                    0.000
                            0.000
                                     0.000 wave.py:339(setsampwidth)
                                   0.000 wave.py:351(setframerate)
           0.000
                    0.000
                            0.000
       1
                                   0.000 wave.py:363(setnframes)
           0.000
                  0.000
                           0.000
       1
       1
           0.000
                  0.000
                          0.000
                                   0.000 wave.py:371(setcomptype)
       1
           0.000
                  0.000
                          0.000
                                   0.000 wave.py:385(setparams)
           0.000
                  0.000
                          0.002
                                    0.002 wave.py:413 (writeframesraw)
       1
       1
           0.000
                  0.000
                          0.002
                                    0.002 wave.py:426(writeframes)
       2
           0.000
                  0.000
                          0.003
                                   0.002 wave.py:431(close)
                  0.000
                          0.000
                                   0.000 wave.py:449( ensure header written)
       2
           0.000
                  0.000
                          0.000
           0.000
                                   0.000 wave.py:459( write header)
       1
                  0.000
       1
           0.000
                            0.000
                                     0.000 wave.py:480( patchheader)
       3
           0.000
                    0.000
                            0.001
                                     0.000 wave.py:492(open)
                    0.000
                            0.000
                                     0.000 {built-in method __new__ of type object at
            0.000
0x7f03afbd49a0}
                                     0.000 {built-in method _struct.pack}
0.003 {built-in method _struct.unpack_from}
 1973510
           0.233
                    0.000
                             0.233
      12
            0.030
                    0.003
                             0.030
            0.000
                    0.000
                                     0.000 {built-in method builtins.abs}
       3
                            0.000
       1
            0.000
                    0.000 809.819 809.819 {built-in method builtins.exec}
```

4	0.000	0.000	0.000	0.000 {built-in method builtins.isinstance}	
33	0.000	0.000	0.000	0.000 {built-in method builtins.len}	
1	0.000	0.000	0.000	0.000 {built-in method builtins.round}	
3	0.001	0.000	0.001	0.000 {built-in method io.open}	
2	0.093	0.046	0.093	0.046 {built-in method numpy.core.multiarray	.array}
1	0.000	0.000	0.000	0.000 {built-in method numpy.core.multiarray	.zeros}
2	0.000	0.000	0.000	0.000 {method 'close' of '_io.BufferedReader	. 1
objects}				_	
1	0.003	0.003	0.003	0.003 {method 'close' of '_io.BufferedWriter	. 1
objects}				_	
1	0.000	0.000	0.000	0.000 {method 'disable' of '_lsprof.Profiler	. 1
objects}					
1973506	0.132	0.000	0.132	0.000 {method 'extend' of 'bytearray' object	
1	0.000	0.000	0.000	0.000 {method 'flush' of '_io.BufferedWriter	. 1
objects}					
20	0.001	0.000	0.001	0.000 {method 'read' of '_io.BufferedReader'	
objects}					
3	0.002	0.001	0.002	0.001 {method 'reduce' of 'numpy.ufunc' obje	:cts}
2	0.000	0.000	0.000	0.000 {method 'seek' of '_io.BufferedReader'	
objects}					
3	0.000	0.000	0.000	0.000 {method 'seek' of '_io.BufferedWriter'	
objects}					
2	0.000	0.000	0.000	0.000 {method 'tell' of '_io.BufferedReader'	
objects}					
3	0.000	0.000	0.000	0.000 {method 'tell' of '_io.BufferedWriter'	
objects}					
6	0.002	0.000	0.002	0.000 {method 'write' of '_io.BufferedWriter	. 1
objects}					

2. Profiler result after algorithm-based optimization with FFT:

3947385 function calls (3947379 primitive calls) in 146.271 seconds

```
ncalls tottime percall cumtime percall filename:lineno(function)
       0.014
               0.014 146.271 146.271 <string>:1(<module>)
              0.000 0.000 0.000 <string>:12( new )
       0.000
       0.000
              0.000
                       0.001
                               0.001 _methods.py:25(_amax)
    1
       0.000
               0.000
                       0.002
                               0.001 _methods.py:28(_amin)
    2
                               0.000 chunk.py:117(tell)
       0.000
               0.000
                       0.000
    4
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                0.000
                        0.001
                                 0.000 chunk.py:122(read)
        0.000
        0.000
                0.000
                         0.000
                                 0.000 chunk.py:145(skip)
    2
                                0.000 chunk.py:52(__init_
    6
        0.000
                0.000
                        0.000
                               0.000 chunk.py:78(getname)
    6
        0.000
                0.000
                        0.000
                               0.000 chunk.py:98(seek)
        0.000
                0.000
                       0.000
    2
    2
       0.000
               0.000
                       0.133
                               0.066 fftpack.py:1013(rfftn)
       0.000
               0.000
                       0.073 0.073 fftpack.py:1142(irfftn)
    1
    2
       0.000
               0.000
                       0.129 0.065 fftpack.py:291(rfft)
    1
       0.004
               0.004
                       0.070 0.070 fftpack.py:380(irfft)
    3
       0.007
               0.002
                       0.188 0.063 fftpack.py:47( raw fft)
    3
       0.000
              0.000
                       0.000 0.000 fftpack.py:613( cook nd args)
    3
       0.000
              0.000 0.000 0.000 fftpack.py:95( unitary)
              0.000
                       0.001
        0.000
                               0.001 fromnumeric.py:2174(amax)
    1
    2
        0.000
                0.000
                       0.002
                                0.001 fromnumeric.py:2275(amin)
                       0.000
    3
        0.000
                0.000
                               0.000 helper.py:257(put_twiddle_factors)
    3
        0.000
                0.000
                        0.000
                                0.000 helper.py:283(pop_twiddle_factors)
    3
        0.000
                0.000
                        0.000
                                 0.000 helper.py:311 (prune cache)
                                0.000 helper.py:53(next_fast_len)
    1
        0.000
                0.000
                        0.000
                       0.000
                               0.000 numeric.py:463(asarray)
    3
        0.000
                0.000
        0.000
               0.000
                       0.000
                               0.000 numerictypes.py:660(issubclass)
    1
        0.000
               0.000
                       0.000 0.000 numerictypes.py:728(issubdtype)
    1
    2
        0.000
               0.000 0.034 0.017 version1.py:20(LoadWaveFile)
        0.733
               0.733 1.112
                               1.112 version1.py:40(SaveWaveFile)
    1
    1
        0.004
              0.004 0.215
                               0.215 version1.py:50(FFTConvolve)
    1
        0.000
              0.000 0.000 0.000 version1.py:63(<listcomp>)
              0.000 0.000 0.000 version1.py:64(<genexpr>)
    2
        0.000
    1 144.792 144.792 144.795 144.795 version1.py:75(Normalize)
       0.000
              0.000 146.257 146.257 version1.py:91(Main)
    1
                       0.000
    2
        0.000
                0.000
                               0.000 wave.py:125(initfp)
                        0.000
                                 0.000 wave.py:156(__init__)
    2
        0.000
                0.000
    2
        0.000
                0.000
                        0.000
                                 0.000 wave.py:169(__del_
    4
        0.000
                0.000
                         0.000
                                 0.000 wave.py:188(close)
    4
        0.000
                0.000
                        0.000
                                0.000 wave.py:198(getnchannels)
        0.000
                0.000
                        0.000
                               0.000 wave.py:201(getnframes)
    4
                       0.000
        0.000
                0.000
                               0.000 wave.py:204(getsampwidth)
    4
    2
        0.000
                0.000
                       0.000
                               0.000 wave.py:207(getframerate)
    2
        0.000
                0.000
                       0.000
                               0.000 wave.py:210(getcomptype)
    2
        0.000
               0.000
                       0.000
                               0.000 wave.py:213(getcompname)
    2
        0.000
              0.000
                       0.000 0.000 wave.py:216(getparams)
    2
        0.000
              0.000
                       0.001
                                0.001 wave.py:233(readframes)
    2
        0.000
              0.000
                       0.000
                               0.000 wave.py:254( read fmt chunk)
        0.000
    1
                0.000
                       0.001
                                0.001 wave.py:291( init )
    1
        0.000
                0.000
                        0.000
                                0.000 wave.py:303(<u>initfp</u>)
    1
        0.000
                0.000
                        0.000
                                0.000 wave.py:315(__del__)
    1
        0.000
                0.000
                        0.000
                                 0.000 wave.py:327 (setnchannels)
        0.000
                0.000
                         0.000
                                 0.000 wave.py:339(setsampwidth)
    1
        0.000
                 0.000
                         0.000
                                 0.000 wave.py:351(setframerate)
```

```
1
            0.000
                    0.000
                             0.000
                                      0.000 wave.py:363(setnframes)
       1
            0.000
                    0.000
                             0.000
                                    0.000 wave.py:371(setcomptype)
                           0.000
       1
            0.000
                    0.000
                                    0.000 wave.py:385(setparams)
                                     0.002 wave.py:413(writeframesraw)
            0.000
                    0.000
                           0.002
       1
       1
           0.000
                   0.000
                           0.002
                                     0.002 wave.py:426(writeframes)
           0.000
                  0.000
                           0.003
                                    0.002 wave.py:431(close)
       2
       2
           0.000
                  0.000
                           0.000
                                    0.000 wave.py:449( ensure header written)
                  0.000
                           0.000
                                    0.000 wave.py:459 (write header)
       1
           0.000
                  0.000
           0.000
                           0.000
                                    0.000 wave.py:480( patchheader)
       1
                           0.001
       3
            0.000
                  0.000
                                     0.000 wave.py:492(open)
            0.000
                  0.000
                           0.000
                                     0.000 {built-in method new of type object at
       2
0x7f11d83f99a0}
           0.239
                    0.000
                             0.239
                                      0.000 {built-in method _struct.pack}
0.003 {built-in method _struct.unpack_from}
 1973509
      12
            0.033
                    0.003
                             0.033
       3
            0.000
                    0.000
                             0.000
                                      0.000 {built-in method builtins.abs}
                    0.000 146.271 146.271 {built-in method builtins.exec}
            0.000
       1
           0.000
                    0.000
                            0.000
                                    0.000 {built-in method builtins.isinstance}
       4
                                      0.000 {built-in method builtins.issubclass}
       2
           0.000
                    0.000
                             0.000
           0.000
                    0.000
                            0.000
                                    0.000 {built-in method builtins.len}
      51
           0.000
                    0.000
                           0.000
       1
                                    0.000 {built-in method builtins.round}
       3
           0.001
                    0.000
                           0.001
                                     0.000 {built-in method io.open}
      15
          0.118
                  0.008
                           0.118
                                    0.008 {built-in method numpy.core.multiarray.array}
                  0.000
       3
          0.000
                           0.000 0.000 {built-in method numpy.core.multiarray.zeros}
          0.059
                  0.059
                           0.059 0.059 {built-in method numpy.fft.fftpack lite.rfftb}
       1
          0.095
                  0.047
                            0.095
                                    0.047 {built-in method numpy.fft.fftpack_lite.rfftf}
       2
       1
           0.027
                    0.027
                            0.027
                                     0.027 {built-in method numpy.fft.fftpack lite.rffti}
                  0.000
                           0.000
                                      0.000 {method 'append' of 'list' objects}
       3
           0.000
      71
            0.000
                    0.000
                             0.000
                                      0.000 {method 'bit_length' of 'int' objects}
            0.000
                   0.000
                             0.000
                                      0.000 {method 'close' of ' io.BufferedReader'
objects}
            0.003
                  0.003
                           0.003
                                    0.003 {method 'close' of ' io.BufferedWriter'
objects}
            0.002
                  0.002
                            0.002
                                      0.002 {method 'copy' of 'numpy.ndarray' objects}
                                    0.000 {method 'disable' of 'lsprof.Profiler'
            0.000
                  0.000
                           0.000
objects}
 1973505
            0.134
                    0.000
                             0.134
                                      0.000 {method 'extend' of 'bytearray' objects}
            0.000
                  0.000
                             0.000
                                      0.000 {method 'flush' of ' io.BufferedWriter'
objects}
       5
            0.000
                    0.000
                             0.000
                                      0.000 {method 'pop' of 'collections.OrderedDict'
objects}
            0.000
                    0.000
                             0.000
                                      0.000 {method 'pop' of 'list' objects}
      20
            0.001
                    0.000
                             0.001
                                      0.000 {method 'read' of ' io.BufferedReader'
objects}
       3
            0.003
                     0.001
                             0.003
                                      0.001 {method 'reduce' of 'numpy.ufunc' objects}
                                      0.000 {method 'seek' of ' io.BufferedReader'
       2
            0.000
                    0.000
                             0.000
objects}
                                      0.000 {method 'seek' of ' io.BufferedWriter'
            0.000
                    0.000
                             0.000
objects}
            0.000
                    0.000
                             0.000
                                      0.000 {method 'tell' of ' io.BufferedReader'
objects}
            0.000
                     0.000
                             0.000
                                      0.000 {method 'tell' of ' io.BufferedWriter'
objects}
                                      0.000 {method 'write' of ' io.BufferedWriter'
            0.002
                    0.000
                             0.002
objects}
```

3. Profiler result after "minimizing work inside loops":

3947385 function calls (3947379 primitive calls) in 79.145 seconds

```
ncalls tottime percall cumtime percall filename: lineno (function)
      0.014
                                 79.145 <string>:1(<module>)
    1
               0.014
                         79.145
                                  0.000 <string>:12(__new__)
         0.000
                 0.000
                         0.000
                                  0.001 _methods.py:25(_amax)
0.001 _methods.py:28(_amin)
        0.000
                 0.000
                          0.001
    2
        0.000
                 0.000
                         0.002
                                0.000 chunk.py:117(tell)
        0.000
                 0.000
                        0.000
    4
                                 0.000 chunk.py:122(read)
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       0.000
                 0.000
                        0.001
                                0.000 chunk.py:145(skip)
    2
       0.000
               0.000
                        0.000
               0.000 0.000 0.000 chunk.py:52( init )
    6
       0.000
       0.000
               0.000 0.000 0.000 chunk.py:78(getname)
    2
        0.000
               0.000 0.000 0.000 chunk.py:98(seek)
    2
        0.000
               0.000
                       0.132 0.066 fftpack.py:1013(rfftn)
        0.000
               0.000
                        0.073
                                0.073 fftpack.py:1142(irfftn)
    1
    2
        0.000
                 0.000
                         0.129
                                0.064 fftpack.py:291(rfft)
    1
         0.004
                 0.004
                          0.070
                                  0.070 fftpack.py:380(irfft)
    3
         0.006
                 0.002
                          0.188
                                  0.063 fftpack.py:47( raw fft)
    3
         0.000
                 0.000
                          0.000
                                  0.000 fftpack.py:613 (cook nd args)
    3
         0.000
                 0.000
                          0.000
                                  0.000 fftpack.py:95(_unitary)
                          0.001
                                  0.001 fromnumeric.py:2174(amax)
    1
        0.000
                 0.000
    2
        0.000
                 0.000
                         0.002
                                  0.001 fromnumeric.py:2275(amin)
    3
        0.000
                 0.000
                         0.000
                                0.000 helper.py:257 (put twiddle factors)
    3
        0.000
                 0.000
                        0.000
                                0.000 helper.py:283(pop twiddle factors)
    3
        0.000
                0.000
                        0.000
                                0.000 helper.py:311(_prune_cache)
        0.000
               0.000
                        0.000
                                0.000 helper.py:53 (next fast len)
    1
    3
        0.000
               0.000
                        0.000
                                0.000 numeric.py:463(asarray)
        0.000
               0.000
                        0.000
                                0.000 numerictypes.py:660(issubclass)
    1
    1
        0.000
               0.000
                        0.000
                                0.000 numerictypes.py:728(issubdtype)
    2
        0.000
               0.000
                        0.035
                                0.017 version2.py:20(LoadWaveFile)
                                 1.121 version2.py:40(SaveWaveFile)
         0.737
                 0.737
                          1.121
    1
    1
         0.004
                 0.004
                         0.214
                                  0.214 version2.py:50 (FFTConvolve)
         0.000
                         0.000
                                  0.000 version2.py:63(<listcomp>)
                 0.000
         0.000
                 0.000
                         0.000
                                  0.000 version2.py:64(<genexpr>)
        77.662
                                  77.665 version2.py:75(Normalize)
    1
                 77.662
                         77.665
                                 79.131 version2.py:91(Main)
    1
        0.000
                 0.000
                         79.131
                                 0.000 wave.py:125(initfp)
    2
         0.000
                 0.000
                         0.000
    2
        0.000
                 0.000
                        0.000
                                0.000 wave.py:156( init
                                0.000 wave.py:169(_ del _)
    2
        0.000
                 0.000
                        0.000
                                0.000 wave.py:188(close)
    4
        0.000
                0.000
                        0.000
         0.000
                 0.000
                        0.000
                                0.000 wave.py:198(getnchannels)
    4
        0.000
               0.000
                        0.000
                                0.000 wave.py:201(getnframes)
    4
        0.000
               0.000
                        0.000
                                0.000 wave.py:204(getsampwidth)
    2
         0.000
                 0.000
                        0.000
                                0.000 wave.py:207(getframerate)
    2
                         0.000
                                0.000 wave.py:210(getcomptype)
         0.000
                 0.000
    2
         0.000
                 0.000
                          0.000
                                  0.000 wave.py:213(getcompname)
    2
         0.000
                 0.000
                          0.000
                                  0.000 wave.py:216(getparams)
         0.000
                 0.000
                          0.001
                                  0.001 wave.py:233(readframes)
         0.000
                 0.000
                          0.000
                                  0.000 wave.py:254(_read_fmt_chunk)
    1
         0.000
                 0.000
                          0.001
                                  0.001 wave.py:291( init
    1
         0.000
                 0.000
                          0.000
                                  0.000 wave.py:303(initfp)
                          0.000
         0.000
                 0.000
                                  0.000 wave.py:315( del )
    1
         0.000
                 0.000
                          0.000
                                  0.000 wave.py:327 (setnchannels)
    1
         0.000
                 0.000
                          0.000
                                0.000 wave.py:339(setsampwidth)
```

```
1
            0.000
                     0.000
                             0.000
                                      0.000 wave.py:351(setframerate)
                            0.000
                                     0.000 wave.py:363(setnframes)
       1
            0.000
                    0.000
                            0.000
                                    0.000 wave.py:371(setcomptype)
       1
            0.000
                    0.000
           0.000
                    0.000
                           0.000
                                    0.000 wave.py:385(setparams)
       1
       1
           0.000
                   0.000
                           0.002
                                     0.002 wave.py:413(writeframesraw)
           0.000
                  0.000 0.002
                                     0.002 wave.py:426(writeframes)
       1
       2
           0.000
                  0.000
                           0.003
                                    0.002 wave.py:431(close)
       2
          0.000
                  0.000 0.000
                                    0.000 wave.py:449( ensure header written)
           0.000
                  0.000 0.000
                                    0.000 wave.py:459 (write header)
       1
       1
           0.000
                  0.000
                           0.000
                                    0.000 wave.py:480(_patchheader)
                  0.000
                           0.001
       3
            0.000
                                     0.000 wave.py:492(open)
            0.000
                  0.000
                           0.000
                                    0.000 {built-in method new of type object at
       2
0x7fa0d3ff59a0}
                                      0.000 {built-in method _struct.pack}
0.003 {built-in method _struct.unpack_from}
 1973509
            0.244
                    0.000
                             0.244
      12
            0.033
                    0.003
                             0.033
            0.000
                    0.000
                             0.000
                                      0.000 {built-in method builtins.abs}
       3
            0.000
                    0.000
                           79.145
                                    79.145 {built-in method builtins.exec}
       1
                                     0.000 {built-in method builtins.isinstance}
           0.000
                   0.000
                             0.000
       4
       2
           0.000
                   0.000
                            0.000
                                    0.000 {built-in method builtins.issubclass}
           0.000
                   0.000
                           0.000
      51
                                    0.000 {built-in method builtins.len}
       1
           0.000
                  0.000
                           0.000 0.000 {built-in method builtins.round}
       3
          0.001
                   0.000
                           0.001 0.000 {built-in method io.open}
      15
          0.111
                    0.007
                            0.111
                                     0.007 {built-in method numpy.core.multiarray.array}
       3
          0.000
                  0.000
                           0.000 0.000 {built-in method numpy.core.multiarray.zeros}
           0.059
                  0.059
                           0.059 0.059 {built-in method numpy.fft.fftpack lite.rfftb}
       1
                   0.047
                                    0.047 {built-in method numpy.fft.fftpack_lite.rfftf}
       2
           0.095
                             0.095
                            0.027
       1
           0.027
                    0.027
                                     0.027 {built-in method numpy.fft.fftpack lite.rffti}
                                      0.000 {method 'append' of 'list' objects}
0.000 {method 'bit_length' of 'int' objects}
0.000 {method 'close' of '_io.BufferedReader'
       3
            0.000
                    0.000
                             0.000
      71
            0.000
                    0.000
                             0.000
       2
            0.000
                    0.000
                             0.000
objects}
            0.003
                  0.003
                           0.003
                                    0.003 {method 'close' of ' io.BufferedWriter'
objects}
                   0.002
                             0.002
                                      0.002 {method 'copy' of 'numpy.ndarray' objects}
            0.002
       1
            0.000
                  0.000
                           0.000
                                      0.000 {method 'disable' of 'lsprof.Profiler'
objects}
                   0.000
 1973505
            0.134
                             0.134
                                      0.000 {method 'extend' of 'bytearray' objects}
                                     0.000 {method 'flush' of ' io.BufferedWriter'
       1
            0.000
                  0.000
                           0.000
objects}
       5
            0.000
                   0.000
                             0.000
                                      0.000 {method 'pop' of 'collections.OrderedDict'
objects}
       2
            0.000
                     0.000
                              0.000
                                      0.000 {method 'pop' of 'list' objects}
                                      0.000 {method 'read' of '_io.BufferedReader'
            0.001
                     0.000
                             0.001
      20
objects}
                              0.003
                                      0.001 {method 'reduce' of 'numpy.ufunc' objects}
            0.003
                     0.001
                                      0.000 {method 'seek' of ' io.BufferedReader'
       2
            0.000
                    0.000
                             0.000
objects}
            0.000
                    0.000
                              0.000
                                      0.000 {method 'seek' of ' io.BufferedWriter'
objects}
            0.000
                     0.000
                              0.000
                                      0.000 {method 'tell' of ' io.BufferedReader'
objects}
            0.000
                     0.000
                              0.000
                                      0.000 {method 'tell' of ' io.BufferedWriter'
objects}
            0.002
                     0.000
                              0.002 0.000 {method 'write' of ' io.BufferedWriter'
objects}
```

4. Profiler result after "unrolling":

3947385 function calls ($394\overline{7}379$ primitive calls) in 1.461 seconds

```
ncalls tottime percall cumtime percall filename:lineno(function)
       0.014
               0.014
                       1.461
                               1.461 <string>:1(<module>)
    1
                                0.000 <string>:12( new )
    2
        0.000
                0.000
                        0.000
       0.000
                0.000
                      0.001
                              0.001 methods.py:25( amax)
       0.000
              0.000
                      0.002
                              0.001 methods.py:28( amin)
                      0.000
                              0.000 chunk.py:117(tell)
      0.000
              0.000
    4
22/16 0.000
              0.000
                      0.001
                              0.000 chunk.py:122(read)
                      0.000
                              0.000 chunk.py:145(skip)
    2
       0.000
              0.000
               0.000
                      0.000
        0.000
                              0.000 chunk.py:52(__init_
    6
                              0.000 chunk.py:78(getname)
                      0.000
    6
        0.000
                0.000
        0.000
                0.000
                        0.000
                                0.000 chunk.py:98(seek)
    2
        0.000
                0.000
                        0.130
                                0.065 fftpack.py:1013(rfftn)
                                0.071 fftpack.py:1142(irfftn)
    1
        0.000
                0.000
                        0.071
                               0.063 fftpack.py:291(rfft)
    2
        0.000
                0.000
                        0.127
                              0.068 fftpack.py:380(irfft)
    1
        0.003
                0.003
                       0.068
    3
       0.006
               0.002
                      0.185 0.062 fftpack.py:47( raw fft)
                      0.000
    3
              0.000
              0.000 0.000 0.000 fftpack.py:95( unitary)
    3
        0.000
    1
        0.000
              0.000 0.001 0.001 fromnumeric.py:2174(amax)
    2
        0.000
              0.000 0.002 0.001 fromnumeric.py:2275(amin)
    3
        0.000
              0.000
                      0.000 0.000 helper.py:257(put_twiddle_factors)
    3
        0.000
              0.000
                      0.000
                              0.000 helper.py:283(pop_twiddle_factors)
    3
                        0.000
                              0.000 helper.py:311( prune cache)
        0.000
                0.000
    1
        0.000
                0.000
                        0.000
                                0.000 helper.py:53 (next fast len)
    3
        0.000
                0.000
                        0.000
                                0.000 numeric.py:463(asarray)
    1
        0.000
                0.000
                        0.000
                                0.000 numerictypes.py:660(issubclass)
    1
        0.000
                0.000
                        0.000
                                0.000 numerictypes.py:728(issubdtype)
    2
        0.000
                0.000
                        0.035
                                0.018 version3.py:20(LoadWaveFile)
                              1.100 version3.py:40(SaveWaveFile)
        0.720
                0.720
                        1.100
    1
                       0.211
        0.004
                0.004
                               0.211 version3.py:50(FFTConvolve)
    1
                              0.000 version3.py:63(<listcomp>)
    1
        0.000
               0.000
                      0.000
              0.000
                      0.000 0.000 version3.py:64(<genexpr>)
    2
        0.000
    1
        0.004
               0.004
                      0.007
                              0.007 version3.pv:75(Normalize)
        0.000
              0.000
                      1.447
                              1.447 version3.py:86(Main)
              0.000
                      0.000
                              0.000 wave.py:125(initfp)
    2
        0.000
    2
        0.000
              0.000
                      0.000
                              0.000 wave.py:156(__init__)
    2
        0.000
                0.000
                      0.000
                              0.000 wave.py:169(__del__)
    4
        0.000
                0.000
                        0.000
                              0.000 wave.py:188(close)
    4
        0.000
                0.000
                        0.000
                                0.000 wave.py:198(getnchannels)
    4
        0.000
                0.000
                        0.000
                                0.000 wave.py:201(getnframes)
        0.000
                0.000
                        0.000
                                0.000 wave.py:204(getsampwidth)
    2
        0.000
                0.000
                        0.000
                                0.000 wave.py:207(getframerate)
    2
                                0.000 wave.py:210(getcomptype)
        0.000
                0.000
                        0.000
    2
                       0.000
                               0.000 wave.py:213(getcompname)
        0.000
                0.000
                              0.000 wave.py:216(getparams)
    2
                      0.000
        0.000
                0.000
    2
        0.000
               0.000
                      0.001
                               0.001 wave.py:233(readframes)
    2
        0.000
              0.000
                      0.000 0.000 wave.py:254( read fmt chunk)
                      0.001 0.001 wave.py:291( init )
    1
        0.000
              0.000
        0.000
              0.000 0.000 0.000 wave.py:303(initfp)
        0.000
              0.000 0.000 0.000 wave.py:315( del )
```

```
1
            0.000
                    0.000
                             0.000
                                      0.000 wave.py:327(setnchannels)
                           0.000
           0.000
                    0.000
                                    0.000 wave.py:339(setsampwidth)
       1
                           0.000
       1
           0.000
                    0.000
                                    0.000 wave.py:351(setframerate)
           0.000
                   0.000
                           0.000
                                    0.000 wave.py:363(setnframes)
       1
       1
           0.000
                  0.000
                           0.000
                                    0.000 wave.py:371(setcomptype)
           0.000
                  0.000 0.000
                                    0.000 wave.py:385(setparams)
       1
       1
           0.000
                  0.000 0.002
                                     0.002 wave.py:413 (writeframesraw)
       1
           0.000
                  0.000 0.002
                                     0.002 wave.py:426(writeframes)
       2
           0.000
                  0.000
                           0.003
                                    0.002 wave.py:431(close)
       2
          0.000
                  0.000
                           0.000
                                    0.000 wave.py:449(_ensure_header_written)
                  0.000
                           0.000
       1
          0.000
                                    0.000 wave.py:459(_write_header)
                           0.000
                  0.000
       1
            0.000
                                     0.000 wave.py:480( patchheader)
                    0.000
                             0.001
                                      0.000 wave.py:492(open)
       3
            0.000
            0.000
                    0.000
                             0.000
                                     0.000 {built-in method new of type object at
0x7efc762759a0}
                    0.000
                                     0.000 {built-in method _struct.pack}
0.003 {built-in method _struct.unpack_from}
            0.241
                             0.241
 1973509
            0.034
                    0.003
                             0.034
      12
           0.000
                    0.000
                             0.000
                                     0.000 {built-in method builtins.abs}
       3
           0.000
                    0.000
                             1.461
                                     1.461 {built-in method builtins.exec}
       1
           0.000
                  0.000
                           0.000
       4
                                    0.000 {built-in method builtins.isinstance}
       2
          0.000
                  0.000
                           0.000 0.000 {built-in method builtins.issubclass}
      51
         0.000
                  0.000
                           0.000 0.000 {built-in method builtins.len}
           0.000
                  0.000
       1
                           0.000 0.000 {built-in method builtins.round}
       3
          0.001
                   0.000 0.001
                                    0.000 {built-in method io.open}
          0.110
                  0.007
      15
                            0.110 0.007 {built-in method numpy.core.multiarray.array}
       3
           0.000
                  0.000
                            0.000
                                    0.000 {built-in method numpy.core.multiarray.zeros}
                   0.058
                           0.058
       1
           0.058
                                    0.058 {built-in method numpy.fft.fftpack lite.rfftb}
                                     0.047 {built-in method numpy.fft.fftpack_lite.rfftf}
       2
           0.093
                    0.047
                             0.093
            0.027
                    0.027
                             0.027
                                      0.027 {built-in method numpy.fft.fftpack lite.rffti}
                                      0.000 {method 'append' of 'list' objects}
       3
           0.000
                    0.000
                             0.000
                                    0.000 {method 'bit_length' of 'int' objects}
0.000 {method 'close' of '_io.BufferedReader'
                  0.000
                           0.000
      71
           0.000
                  0.000
       2
            0.000
                           0.000
objects}
                                    0.003 {method 'close' of ' io.BufferedWriter'
            0.003
                  0.003
                           0.003
objects}
            0.002
                  0.002
                             0.002
                                      0.002 {method 'copy' of 'numpy.ndarray' objects}
            0.000
                  0.000
                             0.000
                                      0.000 {method 'disable' of 'lsprof.Profiler'
objects}
 1973505
            0.132
                    0.000
                             0.132
                                      0.000 {method 'extend' of 'bytearray' objects}
                                      0.000 {method 'flush' of ' io.BufferedWriter'
            0.000
                  0.000
                             0.000
       1
objects}
       5
            0.000
                   0.000
                             0.000
                                      0.000 {method 'pop' of 'collections.OrderedDict'
objects}
                                      0.000 {method 'pop' of 'list' objects}
            0.000
                     0.000
                             0.000
                                      0.000 {method 'read' of ' io.BufferedReader'
      20
            0.001
                    0.000
                             0.001
objects}
                                      0.001 {method 'reduce' of 'numpy.ufunc' objects}
            0.003
                     0.001
                             0.003
                                      0.000 {method 'seek' of ' io.BufferedReader'
       2
            0.000
                    0.000
                             0.000
objects}
            0.000
                    0.000
                             0.000
                                      0.000 {method 'seek' of ' io.BufferedWriter'
objects}
            0.000
                    0.000
                             0.000
                                      0.000 {method 'tell' of ' io.BufferedReader'
objects}
            0.000
                    0.000
                             0.000
                                      0.000 {method 'tell' of ' io.BufferedWriter'
objects}
            0.002
                    0.000
                             0.002
                                    0.000 {method 'write' of ' io.BufferedWriter'
objects}
```

5. Profiler result after "strength reduction":

3947385 function calls ($\overline{3}947379$ primitive calls) in 1.540 seconds

```
ncalls tottime percall cumtime percall filename: lineno (function)
               0.022
                                1.540 <string>:1(<module>)
    1 0.022
                       1.540
       0.000
                       0.000
                 0.000
                                0.000 <string>:12( new )
                        0.001
    1
        0.000
                 0.000
                                  0.001 _methods.py:25(_amax)
                                  0.001 _methods.py:28(_amin)
0.000 chunk.py:117(tell)
        0.000
                 0.000
                         0.002
         0.000
                 0.000
                          0.000
                                  0.000 chunk.py:122(read)
22/16
        0.000
                 0.000
                         0.001
                                0.000 chunk.py:145(skip)
                         0.000
        0.000
                 0.000
    2
                                0.000 chunk.py:52( init
        0.000
                 0.000
                        0.000
    6
        0.000
                 0.000
                        0.000
                                0.000 chunk.py:78 (getname)
    6
    2
        0.000
                 0.000
                       0.000 0.000 chunk.py:98(seek)
    2
        0.000
               0.000
                       0.145
                                0.073 fftpack.py:1013(rfftn)
    1
        0.000
               0.000
                       0.074 0.074 fftpack.py:1142(irfftn)
    2
       0.000
               0.000
                       0.142 0.071 fftpack.py:291(rfft)
        0.004
               0.004
                       0.071 0.071 fftpack.py:380(irfft)
    1
    3
        0.007
                0.002
                       0.202 0.067 fftpack.py:47( raw fft)
                        0.000
    3
        0.000
               0.000
                                0.000 fftpack.py:613( cook nd args)
    3
        0.000
                 0.000
                         0.000
                                0.000 fftpack.py:95( unitary)
    1
         0.000
                 0.000
                         0.001
                                  0.001 fromnumeric.py:2174(amax)
    2
         0.000
                 0.000
                         0.002
                                  0.001 fromnumeric.py:2275(amin)
                                  0.000 helper.py:257(put_twiddle_factors)
    3
         0.000
                 0.000
                         0.000
    3
                                  0.000 helper.py:283(pop twiddle factors)
        0.000
                 0.000
                         0.000
    3
                                  0.000 helper.py:311(_prune_cache)
        0.000
                 0.000
                         0.000
        0.000
                 0.000
                        0.000
                                0.000 helper.py:53 (next fast len)
    1
    3
        0.000
               0.000
                        0.000
                                0.000 numeric.py:463(asarray)
    1
        0.000
               0.000
                       0.000 0.000 numerictypes.py:660(issubclass)
    1
        0.000
               0.000 0.000 0.000 numerictypes.py:728(issubdtype)
    2
        0.000
               0.000 0.035 0.017 version4.py:20(LoadWaveFile)
    1
        0.742
               0.742 1.133 1.133 version4.py:40(SaveWaveFile)
    1
        0.005
               0.005 0.229 0.229 version4.py:50 (FFTConvolve)
        0.000
               0.000
                       0.000
                                0.000 version4.py:63(<listcomp>)
    1
                       0.000
    2
         0.000
                 0.000
                                  0.000 version4.py:64(<genexpr>)
    1
         0.020
                 0.020
                         0.023
                                  0.023 version4.py:75(Normalize)
                                  1.518 version4.py:86(Main)
    1
         0.001
                 0.001
                          1.518
    2
         0.000
                 0.000
                          0.000
                                  0.000 wave.py:125(initfp)
                                  0.000 wave.py:156(__init_
0.000 wave.py:169(__del__
    2
         0.000
                 0.000
                         0.000
    2
         0.000
                 0.000
                         0.000
        0.000
                 0.000
                         0.000
                                0.000 wave.py:188(close)
    4
        0.000
                 0.000
                         0.000
                                0.000 wave.py:198(getnchannels)
    4
        0.000
                 0.000
                        0.000
                                0.000 wave.py:201(getnframes)
    4
    4
        0.000
                 0.000
                        0.000
                                0.000 wave.py:204(getsampwidth)
    2
        0.000
               0.000
                        0.000
                                0.000 wave.py:207(getframerate)
    2
        0.000
               0.000
                       0.000
                                0.000 wave.py:210(getcomptype)
    2
        0.000
               0.000
                       0.000
                                0.000 wave.py:213(getcompname)
    2
        0.000
               0.000
                       0.000 0.000 wave.py:216(getparams)
    2
        0.000
                 0.000
                        0.001
                                0.001 wave.py:233(readframes)
    2
        0.000
                 0.000
                         0.000 0.000 wave.py:254(_read_fmt_chunk)
                               0.001 wave.py:291(__init__)
0.000 wave.py:303(initfp)
                         0.001
    1
         0.000
                 0.000
         0.000
                          0.000
                 0.000
```

```
1
            0.000
                     0.000
                              0.000
                                       0.000 wave.py:315( del )
       1
            0.000
                     0.000
                              0.000
                                       0.000 wave.py:327(setnchannels)
       1
            0.000
                     0.000
                             0.000
                                      0.000 wave.py:339(setsampwidth)
            0.000
                     0.000
                            0.000
                                     0.000 wave.py:351(setframerate)
       1
       1
           0.000
                   0.000
                            0.000
                                     0.000 wave.py:363(setnframes)
           0.000
                   0.000
                            0.000
                                     0.000 wave.py:371(setcomptype)
       1
       1
           0.000
                    0.000
                            0.000
                                     0.000 wave.py:385(setparams)
           0.000
                   0.000
       1
                            0.002
                                      0.002 wave.py:413(writeframesraw)
           0.000
                   0.000
                            0.002
                                      0.002 wave.py:426(writeframes)
       1
       2
           0.000
                    0.000
                             0.004
                                       0.002 wave.py:431(close)
       2
           0.000
                     0.000
                              0.000
                                       0.000 wave.py:449(_ensure_header_written)
       1
            0.000
                     0.000
                              0.000
                                       0.000 wave.py:459(_write_header)
            0.000
                     0.000
                              0.000
                                       0.000 wave.py:480(_patchheader)
       1
            0.000
                     0.000
                              0.001
                                       0.000 wave.py:492(open)
                                       0.000 {built-in method __new__ of type object at
       2
            0.000
                     0.000
                              0.000
0x7fd01492e9a0}
 1973509
            0.247
                     0.000
                              0.247
                                       0.000 {built-in method _struct.pack}
0.003 {built-in method _struct.unpack_from}
                     0.003
                              0.033
      12
            0.033
                                       0.000 {built-in method builtins.abs}
       3
            0.000
                     0.000
                              0.000
           0.000
                     0.000
                            1.540
       1
                                     1.540 {built-in method builtins.exec}
           0.000
                   0.000
                            0.000
                                     0.000 {built-in method builtins.isinstance}
       2
          0.000
                    0.000
                            0.000
                                     0.000 {built-in method builtins.issubclass}
           0.000
                   0.000
                            0.000
      51
                                    0.000 {built-in method builtins.len}
           0.000
                   0.000
                            0.000 0.000 {built-in method builtins.round}
       1
       3
           0.001
                    0.000
                            0.001
                                      0.000 {built-in method io.open}
      15
           0.114
                     0.008
                             0.114
                                      0.008 {built-in method numpy.core.multiarray.array}
       3
            0.000
                     0.000
                              0.000
                                       0.000 {built-in method numpy.core.multiarray.zeros}
       1
            0.061
                     0.061
                              0.061
                                       0.061 {built-in method numpy.fft.fftpack lite.rfftb}
            0.105
                     0.052
                              0.105
                                       0.052 {built-in method numpy.fft.fftpack_lite.rfftf}
       1
            0.030
                     0.030
                              0.030
                                       0.030 {built-in method numpy.fft.fftpack lite.rffti}
                                       0.000 {method 'append' of 'list' objects}
       3
            0.000
                     0.000
                              0.000
                                      0.000 {method 'bit_length' of 'int' objects}
0.000 {method 'close' of '_io.BufferedReader'
       71
            0.000
                    0.000
                              0.000
       2
            0.000
                   0.000
                            0.000
objects}
            0.004
                   0.004
                            0.004
                                       0.004 {method 'close' of ' io.BufferedWriter'
objects}
                     0.002
                              0.002
            0.002
                                       0.002 {method 'copy' of 'numpy.ndarray' objects}
       1
            0.000
                   0.000
                              0.000
                                       0.000 {method 'disable' of 'lsprof.Profiler'
objects}
 1973505
            0.137
                     0.000
                              0.137
                                       0.000 {method 'extend' of 'bytearray' objects}
                                       0.000 {method 'flush' of ' io.BufferedWriter'
            0.000
                     0.000
                              0.000
       1
objects}
            0.000
                     0.000
                              0.000
                                       0.000 {method 'pop' of 'collections.OrderedDict'
objects}
                     0.000
                                       0.000 {method 'pop' of 'list' objects}
            0.000
                              0.000
                                       0.000 {method 'read' of '_io.BufferedReader'
            0.001
                     0.000
                              0.001
      20
objects}
       3
            0.003
                     0.001
                              0.003
                                       0.001 {method 'reduce' of 'numpy.ufunc' objects}
       2
            0.000
                     0.000
                              0.000
                                       0.000 {method 'seek' of ' io.BufferedReader'
objects}
            0.000
                     0.000
                              0.000
                                       0.000 {method 'seek' of ' io.BufferedWriter'
objects}
                                       0.000 {method 'tell' of ' io.BufferedReader'
            0.000
                     0.000
                              0.000
objects}
            0.000
                     0.000
                              0.000
                                       0.000 {method 'tell' of ' io.BufferedWriter'
objects}
            0.002
                     0.000
                              0.002
                                       0.000 {method 'write' of ' io.BufferedWriter'
objects}
```

6. Profiler result after "initialize at compile time":

3947385 function calls (3947379 primitive calls) in 1.538 seconds

```
ncalls tottime percall cumtime percall filename: lineno (function)
    1
        0.022
                 0.022
                        1.538
                                 1.538 <string>:1(<module>)
                                  0.000 <string>:12(__new__)
         0.000
                 0.000
                          0.000
                                  0.001 methods.py: 25 ( amax)
        0.000
                 0.000
                          0.001
                 0.000
                        0.002
                                 0.001 methods.py:28 ( amin)
    2
        0.000
                                0.000 chunk.py:117(tell)
    4
       0.000
                 0.000
                        0.000
22/16
       0.000
                 0.000
                        0.002
                                0.000 chunk.py:122(read)
    2
        0.000
               0.000
                        0.000 0.000 chunk.py:145(skip)
    6
        0.000
               0.000
                        0.000 0.000 chunk.py:52(__init__)
    6
        0.000
               0.000
                        0.000
                                0.000 chunk.py:78(getname)
    2
                                0.000 chunk.py:98(seek)
        0.000
                 0.000
                        0.000
    2
        0.000
                 0.000
                          0.131
                                0.066 fftpack.py:1013(rfftn)
    1
         0.000
                 0.000
                          0.074
                                  0.074 fftpack.py:1142(irfftn)
    2
         0.000
                 0.000
                          0.128
                                  0.064 fftpack.py:291(rfft)
         0.004
                 0.004
                          0.071
                                   0.071 fftpack.py:380(irfft)
    1
    3
         0.006
                 0.002
                          0.188
                                  0.063 fftpack.py:47( raw fft)
                                  0.000 fftpack.py:613(_cook_nd_args)
    3
        0.000
                 0.000
                          0.000
    3
        0.000
                 0.000
                          0.000
                                  0.000 fftpack.py:95( unitary)
        0.000
                 0.000
                          0.001
                                  0.001 fromnumeric.py:2174(amax)
    1
    2
        0.000
                 0.000
                          0.002
                                  0.001 fromnumeric.py:2275(amin)
        0.000
                 0.000
                          0.000
                                 0.000 helper.py:257(put twiddle factors)
    3
    3
        0.000
                 0.000
                        0.000
                                 0.000 helper.py:283(pop_twiddle_factors)
    3
        0.000
               0.000
                        0.000
                                 0.000 helper.py:311( prune cache)
                                 0.000 helper.py:53(next_fast_len)
    1
        0.000
               0.000
                        0.000
                 0.000
                                 0.000 numeric.py:463(asarray)
        0.000
                        0.000
    3
         0.000
                 0.000
                          0.000
                                 0.000 numerictypes.py:660(issubclass)
    1
    1
         0.000
                 0.000
                          0.000
                                  0.000 numerictypes.py:728(issubdtype)
    2
                                  0.017 version5.py:21(LoadWaveFile)
         0.000
                 0.000
                          0.035
         0.745
                 0.745
                          1.141
                                  1.141 version5.py:41(SaveWaveFile)
         0.005
                 0.005
                          0.215
                                  0.215 version5.py:51(FFTConvolve)
    1
         0.000
                 0.000
                          0.000
                                  0.000 version5.py:64(<listcomp>)
                                 0.000 version5.py:65(<genexpr>)
    2
         0.000
                 0.000
                          0.000
                                 0.027 version5.py:76(Normalize)
         0.024
                 0.024
                         0.027
    1
    1
         0.001
                 0.001
                         1.515
                                 1.515 version5.py:87 (Main)
    2
         0.000
                 0.000
                        0.000
                                0.000 wave.py:125(initfp)
    2
                 0.000
                        0.000
                                0.000 wave.py:156(__init__)
         0.000
    2
         0.000
                 0.000
                        0.000
                                0.000 wave.py:169( del )
    4
         0.000
                 0.000
                        0.000
                                0.000 wave.py:188(close)
    4
         0.000
                 0.000
                        0.000
                                 0.000 wave.py:198(getnchannels)
                 0.000
                          0.000
                                  0.000 wave.py:201(getnframes)
    4
         0.000
    4
         0.000
                 0.000
                          0.000
                                  0.000 wave.py:204(getsampwidth)
    2
         0.000
                 0.000
                          0.000
                                  0.000 wave.py:207(getframerate)
    2
         0.000
                 0.000
                          0.000
                                  0.000 wave.py:210(getcomptype)
    2
         0.000
                 0.000
                          0.000
                                  0.000 wave.py:213 (getcompname)
    2
         0.000
                 0.000
                          0.000
                                   0.000 wave.py:216(getparams)
                                  0.001 wave.py:233(readframes)
    2
         0.000
                 0.000
                          0.002
    2
         0.000
                 0.000
                          0.000
                                   0.000 wave.py:254 (read fmt chunk)
         0.000
                 0.000
                          0.001
                                  0.001 wave.py:291( init )
```

```
0.000
       1
                     0.000
                             0.000
                                      0.000 wave.py:303(initfp)
       1
            0.000
                     0.000
                             0.000
                                      0.000 wave.py:315( del )
       1
            0.000
                    0.000
                             0.000
                                     0.000 wave.py:327(setnchannels)
            0.000
                    0.000
                            0.000
                                    0.000 wave.py:339(setsampwidth)
       1
       1
           0.000
                   0.000
                           0.000
                                    0.000 wave.py:351(setframerate)
           0.000
                   0.000
                           0.000
                                    0.000 wave.py:363(setnframes)
       1
       1
           0.000
                   0.000
                           0.000
                                    0.000 wave.py:371(setcomptype)
           0.000
       1
                   0.000
                           0.000
                                    0.000 wave.py:385(setparams)
           0.000
                   0.000
                           0.002
                                     0.002 wave.py:413(writeframesraw)
       1
       1
           0.000
                    0.000
                             0.002
                                      0.002 wave.py:426(writeframes)
       2
           0.000
                    0.000
                             0.003
                                      0.002 wave.py:431(close)
       2
            0.000
                    0.000
                             0.000
                                      0.000 wave.py:449(_ensure_header_written)
            0.000
                    0.000
                             0.000
                                      0.000 wave.py:459(_write_header)
       1
            0.000
                     0.000
                             0.000
                                      0.000 wave.py:480( patchheader)
       3
            0.000
                     0.000
                             0.001
                                      0.000 wave.py:492(open)
                                      0.000 {built-in method new of type object at
       2
            0.000
                    0.000
                             0.000
0x7f86656f19a0}
                                      0.000 {built-in method _struct.pack}
0.003 {built-in method _struct.unpack_from}
 1973509
            0.251
                    0.000
                             0.251
            0.033
                    0.003
                             0.033
      12
            0.000
                    0.000
                             0.000
                                      0.000 {built-in method builtins.abs}
       3
       1
           0.000
                    0.000
                           1.538
                                    1.538 {built-in method builtins.exec}
           0.000
                   0.000
                           0.000 0.000 {built-in method builtins.isinstance}
           0.000
                   0.000
                           0.000
       2
                                    0.000 {built-in method builtins.issubclass}
      51
         0.000
                  0.000
                           0.000
                                    0.000 {built-in method builtins.len}
                  0.000
           0.000
                           0.000
       1
                                    0.000 {built-in method builtins.round}
       3
           0.001
                    0.000
                             0.001
                                     0.000 {built-in method io.open}
      15
           0.113
                    0.008
                             0.113
                                      0.008 {built-in method numpy.core.multiarray.array}
       3
            0.000
                    0.000
                             0.000
                                      0.000 {built-in method numpy.core.multiarray.zeros}
            0.061
                    0.061
                             0.061
                                      0.061 {built-in method numpy.fft.fftpack_lite.rfftb}
       2
                                      0.047 {built-in method numpy.fft.fftpack lite.rfftf}
            0.094
                    0.047
                             0.094
                                      0.027 {built-in method numpy.fft.fftpack lite.rffti}
       1
            0.027
                    0.027
                             0.027
                                      0.000 {method 'append' of 'list' objects}
       3
           0.000
                    0.000
                            0.000
                                      0.000 {method 'bit length' of 'int' objects}
      71
                   0.000
                           0.000
            0.000
                                     0.000 {method 'close' of ' io.BufferedReader'
       2
            0.000
                   0.000
                           0.000
objects}
            0.003
                  0.003
                             0.003
                                      0.003 {method 'close' of ' io.BufferedWriter'
objects}
                    0.002
                             0.002
       1
            0.002
                                      0.002 {method 'copy' of 'numpy.ndarray' objects}
                                      0.000 {method 'disable' of 'lsprof.Profiler'
       1
            0.000
                   0.000
                             0.000
objects}
 1973505
                     0.000
                             0.138
            0.138
                                      0.000 {method 'extend' of 'bytearray' objects}
            0.000
                    0.000
                             0.000
                                      0.000 {method 'flush' of ' io.BufferedWriter'
       1
objects}
            0.000
                     0.000
                             0.000
                                      0.000 {method 'pop' of 'collections.OrderedDict'
objects}
            0.000
                     0.000
                              0.000
                                      0.000 {method 'pop' of 'list' objects}
                                      0.000 {method 'read' of ' io.BufferedReader'
            0.002
                     0.000
                             0.002
      20
objects}
            0.004
                     0.001
                              0.004
                                      0.001 {method 'reduce' of 'numpy.ufunc' objects}
       2
            0.000
                     0.000
                             0.000
                                      0.000 {method 'seek' of ' io.BufferedReader'
objects}
                                      0.000 {method 'seek' of ' io.BufferedWriter'
            0.000
                     0.000
                              0.000
objects}
            0.000
                     0.000
                              0.000
                                      0.000 {method 'tell' of ' io.BufferedReader'
objects}
            0.000
                     0.000
                              0.000
                                      0.000 {method 'tell' of ' io.BufferedWriter'
objects}
            0.002
                     0.000
                              0.002
                                      0.000 {method 'write' of ' io.BufferedWriter'
objects}
```

7. Profiler result after "exploit algebraic identities":

3947382 function calls (3947376 primitive calls) in 1.564 seconds

```
ncalls tottime percall cumtime percall filename: lineno (function)
    1
        0.015
                 0.015
                         1.564
                                 1.564 <string>:1(<module>)
                                   0.000 <string>:12(__new__)
    2
         0.000
                  0.000
                          0.000
                                   0.001 methods.py: 25 ( amax)
    1
        0.000
                 0.000
                          0.001
                 0.000
                          0.001
                                  0.001 methods.py:28( amin)
        0.000
    1
                                 0.000 chunk.py:117(tell)
    4
        0.000
                 0.000
                        0.000
22/16
       0.000
                 0.000
                        0.002
                                 0.000 chunk.py:122(read)
    2
        0.000
                0.000
                        0.000
                                 0.000 chunk.py:145(skip)
    6
        0.000
               0.000
                        0.000 0.000 chunk.py:52(__init__)
    6
        0.000
                0.000
                        0.000
                                 0.000 chunk.py:78(getname)
                                 0.000 chunk.py:98(seek)
    2
        0.000
                 0.000
                          0.000
    2
         0.000
                 0.000
                          0.143
                                   0.071 fftpack.py:1013(rfftn)
    1
         0.000
                 0.000
                          0.074
                                   0.074 fftpack.py:1142(irfftn)
    2
         0.000
                 0.000
                          0.139
                                   0.070 fftpack.py:291(rfft)
         0.003
                  0.003
                          0.071
                                   0.071 fftpack.py:380(irfft)
    1
    3
         0.007
                  0.002
                          0.200
                                   0.067 fftpack.py:47(_raw_fft)
                                   0.000 fftpack.py:613(_cook_nd_args)
    3
         0.000
                 0.000
                          0.000
    3
        0.000
                 0.000
                          0.000
                                   0.000 fftpack.py:95( unitary)
        0.000
                 0.000
                          0.001
                                   0.001 fromnumeric.py:2174(amax)
    1
    1
         0.000
                 0.000
                          0.001
                                   0.001 fromnumeric.py:2275(amin)
                 0.000
                          0.000
                                   0.000 helper.py:257 (put twiddle factors)
    3
        0.000
    3
        0.000
                 0.000
                          0.000
                                   0.000 helper.py:283(pop_twiddle_factors)
    3
        0.000
                 0.000
                        0.000
                                 0.000 helper.py:311( prune cache)
                                 0.000 helper.py:53(next_fast_len)
    1
         0.000
                 0.000
                        0.000
                 0.000
         0.000
                        0.000
    3
                                 0.000 numeric.py:463(asarray)
         0.000
                 0.000
                          0.000
                                 0.000 numerictypes.py:660(issubclass)
    1
    1
         0.000
                 0.000
                          0.000
                                   0.000 numerictypes.py:728(issubdtype)
    2
         0.000
                 0.000
                          0.034
                                   0.017 version6.py:21(LoadWaveFile)
    1
         0.786
                 0.786
                          1.169
                                   1.169 version6.py:41(SaveWaveFile)
         0.005
                 0.005
                          0.227
                                   0.227 version6.py:51(FFTConvolve)
    1
         0.000
                 0.000
                          0.000
                                   0.000 version6.py:64(<listcomp>)
                                  0.000 version6.py:65(<genexpr>)
    2
         0.000
                 0.000
                          0.000
                                  0.022 version6.py:76(Normalize)
         0.020
                 0.020
                          0.022
    1
                                 1.549 version6.py:85(Main)
    1
         0.001
                 0.001
                         1.549
    2
         0.000
                 0.000
                        0.000
                                 0.000 wave.py:125(initfp)
    2
                        0.000
                                 0.000 wave.py:156(__init__)
         0.000
                 0.000
    2
         0.000
                 0.000
                        0.000
                                 0.000 wave.py:169( del )
    4
         0.000
                 0.000
                        0.000
                                 0.000 wave.py:188(close)
    4
         0.000
                 0.000
                          0.000
                                 0.000 wave.py:198(getnchannels)
                          0.000
                                   0.000 wave.py:201(getnframes)
    4
         0.000
                 0.000
    4
         0.000
                 0.000
                          0.000
                                   0.000 wave.py:204(getsampwidth)
    2
         0.000
                 0.000
                          0.000
                                   0.000 wave.py:207(getframerate)
    2
         0.000
                 0.000
                          0.000
                                   0.000 wave.py:210(getcomptype)
    2
         0.000
                  0.000
                          0.000
                                   0.000 wave.py:213 (getcompname)
    2
         0.000
                  0.000
                          0.000
                                   0.000 wave.py:216(getparams)
    2
         0.000
                  0.000
                          0.002
                                   0.001 wave.py:233 (readframes)
    2
         0.000
                  0.000
                          0.000
                                   0.000 wave.py:254 (read fmt chunk)
         0.000
                  0.000
                          0.001
                                   0.001 wave.py:291( init )
```

```
0.000
       1
                     0.000
                              0.000
                                       0.000 wave.py:303(initfp)
            0.000
                                      0.000 wave.py:315( del )
       1
                     0.000
                             0.000
       1
            0.000
                    0.000
                            0.000
                                     0.000 wave.py:327 (setnchannels)
            0.000
                    0.000
                            0.000
                                     0.000 wave.py:339(setsampwidth)
       1
       1
           0.000
                   0.000
                            0.000
                                    0.000 wave.py:351(setframerate)
           0.000
                   0.000
                           0.000
                                    0.000 wave.py:363(setnframes)
       1
       1
           0.000
                   0.000
                           0.000
                                    0.000 wave.py:371(setcomptype)
           0.000
                   0.000
                           0.000
       1
                                    0.000 wave.py:385(setparams)
           0.000
                   0.000
                           0.002
                                      0.002 wave.py:413(writeframesraw)
       1
       1
            0.000
                    0.000
                            0.002
                                      0.002 wave.py:426(writeframes)
       2
            0.000
                    0.000
                             0.003
                                      0.002 wave.py:431(close)
       2
            0.000
                    0.000
                              0.000
                                      0.000 wave.py:449(_ensure_header_written)
            0.000
                     0.000
                              0.000
                                       0.000 wave.py:459(_write_header)
       1
            0.000
                     0.000
                              0.000
                                       0.000 wave.py:480( patchheader)
       3
            0.000
                     0.000
                              0.001
                                       0.000 wave.py:492(open)
                                      0.000 {built-in method __new__ of type object at
            0.000
                     0.000
                              0.000
       2
0x7fe951b179a0}
                                      0.000 {built-in method _struct.pack}
0.003 {built-in method _struct.unpack_from}
 1973509
           0.241
                    0.000
                             0.241
            0.032
                    0.003
                            0.032
      12
            0.000
                    0.000
                             0.000
                                      0.000 {built-in method builtins.abs}
       2
       1
           0.000
                    0.000
                           1.564 {built-in method builtins.exec}
           0.000
                   0.000
                           0.000
                                    0.000 {built-in method builtins.isinstance}
           0.000
                   0.000
                            0.000 0.000 {built-in method builtins.issubclass}
       2
      51
          0.000
                   0.000
                           0.000 0.000 {built-in method builtins.len}
           0.000
                   0.000
                            0.000
                                    0.000 {built-in method builtins.max}
       1
       1
           0.000
                    0.000
                             0.000
                                    0.000 {built-in method builtins.round}
                    0.000
       3
            0.001
                             0.001
                                     0.000 {built-in method io.open}
      15
            0.113
                     0.008
                             0.113
                                      0.008 {built-in method numpy.core.multiarray.array}
       3
            0.000
                     0.000
                              0.000
                                      0.000 {built-in method numpy.core.multiarray.zeros}
       1
            0.061
                     0.061
                             0.061
                                      0.061 {built-in method numpy.fft.fftpack lite.rfftb}
                             0.103
                                      0.052 {built-in method numpy.fft.fftpack lite.rfftf}
       2
            0.103
                    0.052
                                      0.029 {built-in method numpy.fft.fftpack lite.rffti}
       1
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                             0.029
                                      0.000 {method 'append' of 'list' objects}
       3
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                                       0.000 {method 'bit length' of 'int' objects}
      71
            0.000
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                                     0.000 {method 'close' of ' io.BufferedReader'
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objects}
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                                       0.003 {method 'close' of ' io.BufferedWriter'
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objects}
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                                       0.002 {method 'copy' of 'numpy.ndarray' objects}
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                                       0.000 {method 'disable' of 'lsprof.Profiler'
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objects}
                                       0.000 {method 'extend' of 'bytearray' objects}
0.000 {method 'flush' of '_io.BufferedWriter'
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objects}
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                                       0.000 {method 'pop' of 'collections.OrderedDict'
objects}
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                                       0.000 {method 'pop' of 'list' objects}
                                       0.000 {method 'read' of ' io.BufferedReader'
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objects}
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                                       0.001 {method 'reduce' of 'numpy.ufunc' objects}
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objects}
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objects}
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                                       0.000 {method 'tell' of ' io.BufferedReader'
objects}
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                              0.000
                                       0.000 {method 'tell' of ' io.BufferedWriter'
objects}
                                      0.000 {method 'write' of ' io.BufferedWriter'
            0.002
                     0.000
                              0.002
objects}
```

8. Profile result after compiler level optimization:

3947382 function calls (3947376 primitive calls) in 1.494 seconds

```
ncalls tottime percall cumtime percall filename: lineno (function)
    1
        0.015
                 0.015
                         1.494
                                  1.494 <string>:1(<module>)
                                   0.000 <string>:12(__new__)
    2
         0.000
                  0.000
                          0.000
                                   0.001 methods.py: 25 ( amax)
    1
        0.000
                 0.000
                          0.001
                 0.000
                          0.001
                                  0.001 methods.py:28( amin)
        0.000
    1
                                 0.000 chunk.py:117(tell)
    4
        0.000
                 0.000
                        0.000
22/16
       0.000
                 0.000
                        0.002
                                 0.000 chunk.py:122(read)
    2
        0.000
                 0.000
                        0.000
                                 0.000 chunk.py:145(skip)
    6
        0.000
                0.000
                        0.000 0.000 chunk.py:52(__init__)
    6
        0.000
                 0.000
                        0.000
                                 0.000 chunk.py:78(getname)
                                 0.000 chunk.py:98(seek)
    2
        0.000
                 0.000
                          0.000
    2
         0.000
                 0.000
                          0.132
                                   0.066 fftpack.py:1013(rfftn)
    1
         0.000
                 0.000
                          0.072
                                   0.072 fftpack.py:1142(irfftn)
    2
         0.000
                  0.000
                          0.128
                                   0.064 fftpack.py:291(rfft)
         0.003
                  0.003
                          0.068
                                   0.068 fftpack.py:380(irfft)
    1
    3
         0.006
                  0.002
                          0.187
                                   0.062 fftpack.py:47( raw fft)
                                   0.000 fftpack.py:613(_cook_nd_args)
    3
         0.000
                  0.000
                          0.000
    3
        0.000
                 0.000
                          0.000
                                   0.000 fftpack.py:95( unitary)
        0.000
                 0.000
                          0.001
                                   0.001 fromnumeric.py:2174(amax)
    1
    1
         0.000
                 0.000
                          0.001
                                   0.001 fromnumeric.py:2275(amin)
                 0.000
                          0.000
                                   0.000 helper.py:257 (put twiddle factors)
    3
         0.000
    3
        0.000
                 0.000
                          0.000
                                   0.000 helper.py:283(pop_twiddle_factors)
    3
         0.000
                 0.000
                          0.000
                                   0.000 helper.py:311( prune cache)
                                 0.000 helper.py:53(next_fast_len)
    1
         0.000
                 0.000
                          0.000
                 0.000
                                 0.000 numeric.py:463(asarray)
         0.000
                          0.000
    3
         0.000
                 0.000
                          0.000
                                   0.000 numerictypes.py:660(issubclass)
    1
    1
         0.000
                 0.000
                          0.000
                                   0.000 numerictypes.py:728(issubdtype)
    2
         0.000
                 0.000
                          0.036
                                   0.018 version6.py:21(LoadWaveFile)
    1
         0.731
                  0.731
                          1.112
                                   1.112 version6.py:41(SaveWaveFile)
         0.004
                  0.004
                          0.213
                                   0.213 version6.py:51(FFTConvolve)
    1
         0.000
                 0.000
                          0.000
                                   0.000 version6.py:64(<listcomp>)
                                   0.000 version6.py:65(<genexpr>)
    2
         0.000
                 0.000
                          0.000
                                  0.022 version6.py:76(Normalize)
         0.020
                 0.020
                          0.022
    1
                                 1.479 version6.py:85(Main)
    1
         0.000
                 0.000
                         1.479
    2
         0.000
                 0.000
                         0.000
                                 0.000 wave.py:125(initfp)
    2
                 0.000
                         0.000
                                 0.000 wave.py:156(__init__)
         0.000
    2
         0.000
                 0.000
                        0.000
                                 0.000 wave.py:169( del )
    4
         0.000
                 0.000
                          0.000
                                 0.000 wave.py:188(close)
    4
         0.000
                 0.000
                          0.000
                                 0.000 wave.py:198(getnchannels)
                          0.000
                                   0.000 wave.py:201(getnframes)
    4
         0.000
                 0.000
    4
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                 0.000
                          0.000
                                   0.000 wave.py:204(getsampwidth)
    2
         0.000
                 0.000
                          0.000
                                   0.000 wave.py:207(getframerate)
    2
         0.000
                  0.000
                          0.000
                                   0.000 wave.py:210(getcomptype)
    2
         0.000
                  0.000
                          0.000
                                   0.000 wave.py:213 (getcompname)
    2
         0.000
                  0.000
                           0.000
                                   0.000 wave.py:216(getparams)
    2
         0.000
                  0.000
                           0.002
                                   0.001 wave.py:233 (readframes)
    2
         0.000
                  0.000
                           0.000
                                   0.000 wave.py:254 (read fmt chunk)
         0.000
                  0.000
                           0.001
                                   0.001 wave.py:291( init )
```

```
0.000
       1
                     0.000
                              0.000
                                      0.000 wave.py:303(initfp)
            0.000
                             0.000
                                      0.000 wave.py:315( del )
       1
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                    0.000
                            0.000
                                     0.000 wave.py:327 (setnchannels)
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                                     0.000 wave.py:339(setsampwidth)
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                                    0.000 wave.py:363(setnframes)
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                                    0.000 wave.py:371(setcomptype)
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                           0.000
       1
                                    0.000 wave.py:385(setparams)
           0.000
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                           0.002
                                      0.002 wave.py:413(writeframesraw)
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       1
           0.000
                    0.000
                            0.002
                                      0.002 wave.py:426(writeframes)
       2
            0.000
                    0.000
                             0.004
                                      0.002 wave.py:431(close)
       2
            0.000
                    0.000
                             0.000
                                      0.000 wave.py:449(_ensure_header_written)
            0.000
                    0.000
                             0.000
                                      0.000 wave.py:459(_write_header)
       1
            0.000
                     0.000
                              0.000
                                      0.000 wave.py:480( patchheader)
       3
            0.000
                     0.000
                              0.001
                                      0.000 wave.py:492(open)
                                      0.000 {built-in method __new__ of type object at
       2
            0.000
                     0.000
                             0.000
0x7f04bb6b39a0}
                                    0.000 {built-in method _struct.pack}
0.003 {built-in method _struct.unpack_from}
 1973509
           0.240
                   0.000
                            0.240
            0.034
                   0.003
                            0.034
      12
            0.000
                    0.000
                             0.000
                                      0.000 {built-in method builtins.abs}
       2
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                           1.494
                                    1.494 {built-in method builtins.exec}
           0.000
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                                    0.000 {built-in method builtins.isinstance}
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                                      0.027 {built-in method numpy.fft.fftpack lite.rffti}
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                                     0.000 {method 'append' of 'list' objects}
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objects}
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objects}
```