View parameters, plot waveform, compute and display spectrum. Verify that the frequency of the sinusoid (as measured using the FFT) is the expected frequency.

```
clear
```

Load .wav file

```
[x, Fs] = audioread('author_f.wav');
[nbits, opts] = audioread('author_f.wav');

whos
```

```
  Name           Size             Bytes  Class     Attributes

  Fs             1x1                  8  double
  nbits      25500x1             204000  double
  opts           1x1                  8  double
  x          25500x1             204000  double
```

```
Fs
```

```
Fs =
       16000
```

```
nbits
```

```
nbits = 25500×1
   0.915527343750000
   0.305175781250000
                   0
                   0
                   0
                   0
                   0
  -0.305175781250000
                   0
                   0
      ⋮
```

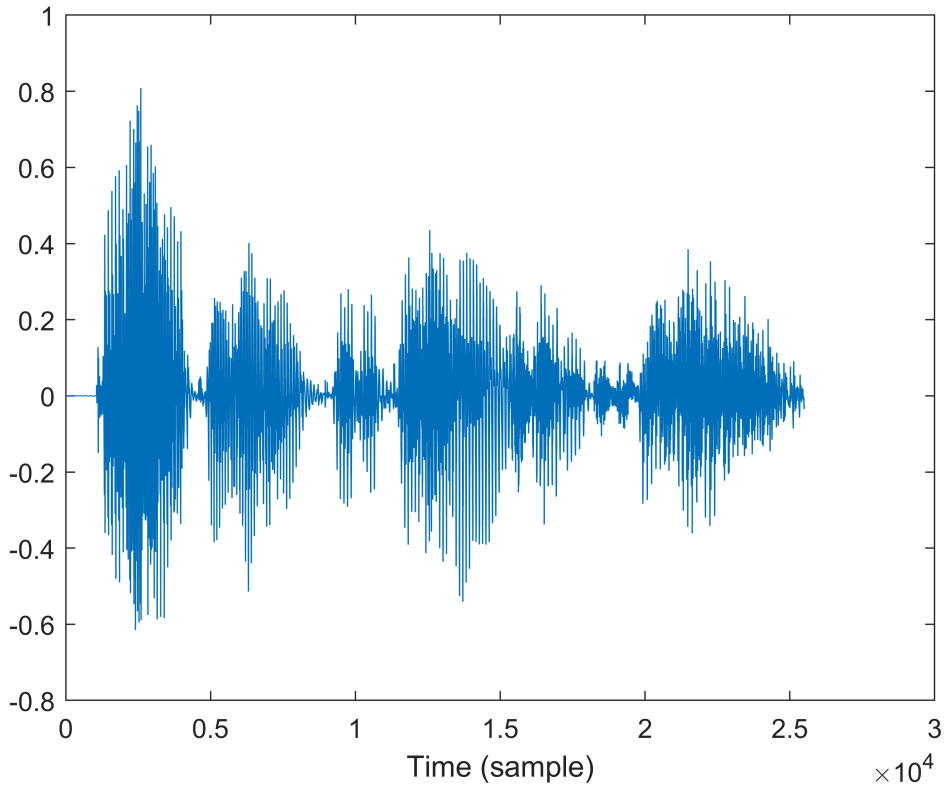
```
opts
```

```
opts =
       16000
```

```
soundsc(x, Fs)
```

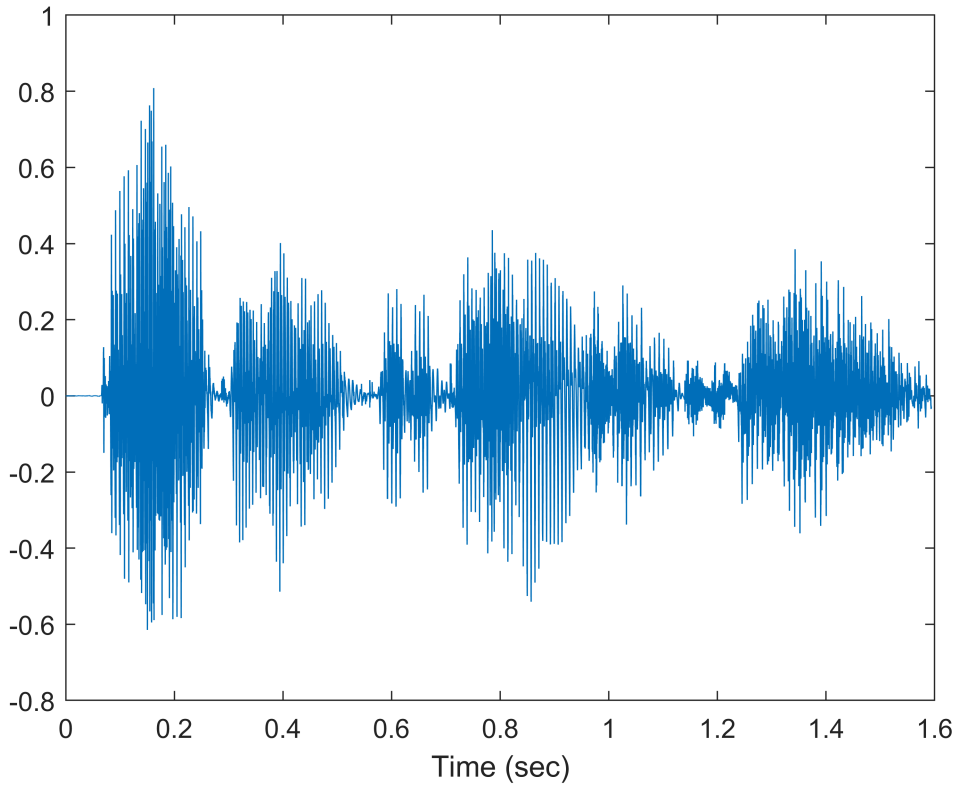
Plot waveform

```
figure(1)
clf
plot(x)
xlabel('Time (sample)')
```



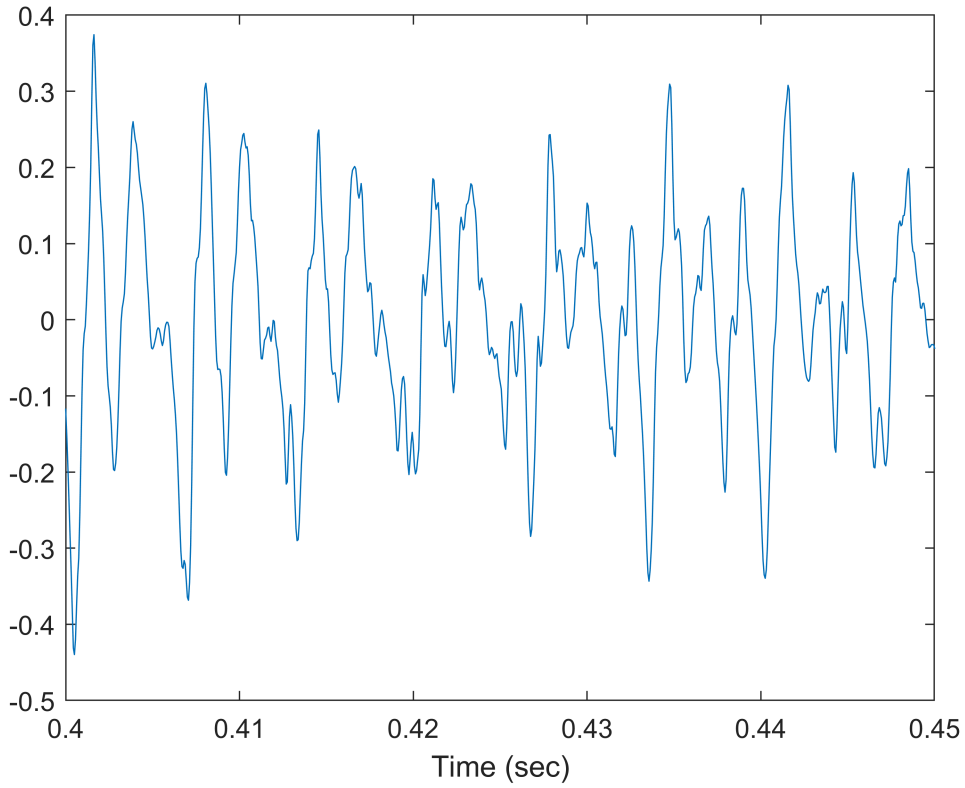
Time axis in seconds

```
N = length(x);
t = (1:N)/Fs;

figure(1)
clf
plot(t, x)
xlabel('Time (sec)')
```



Zoom in to 50 msec

```
xlim(0.4 + [0 0.050])
```




```
%imp = [1  zero(1,N)];
%h = filter (x, imp)

%figure(1)
%clf
%stem(0:N,h)
%xlabel('Discrete time(n)')
%title('impulse response')
```

Frequency spectrum

Use Fast Fourier Transform (FFT)

```
% Use power of 2 for FFT efficiency
N = length(x)
```

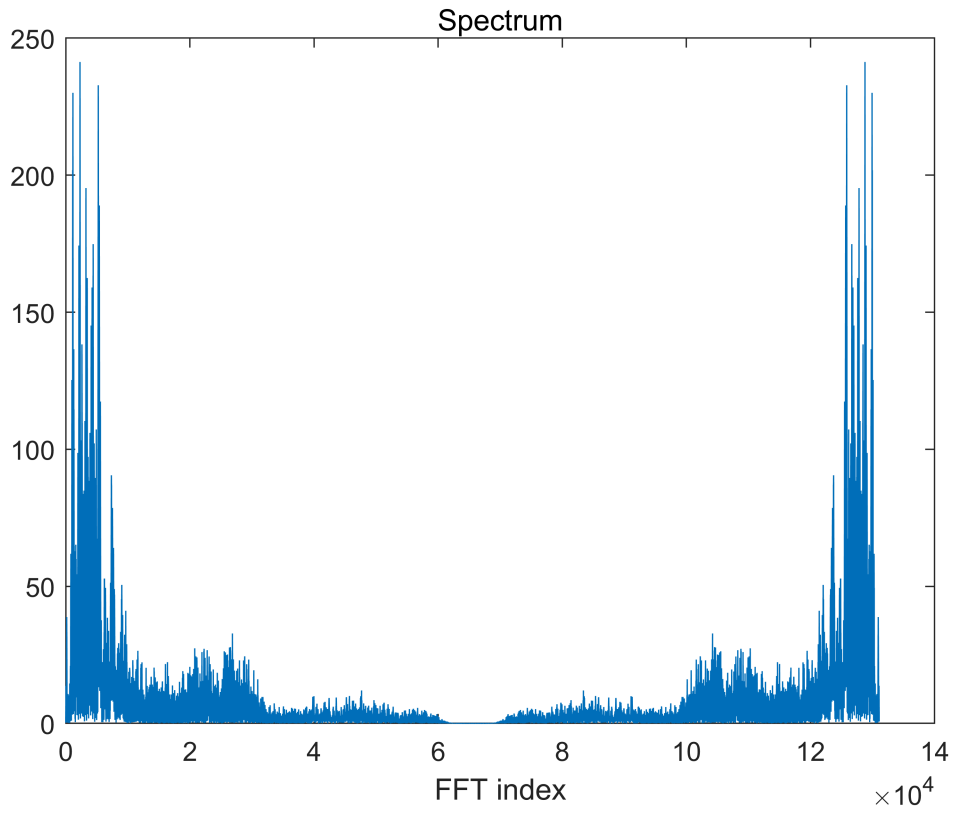
```
N =
       25500
```

```
Nfft = 2^ceil(2+log2(N))        % Use FFT length longer than signal length
```

```
Nfft =
      131072
```

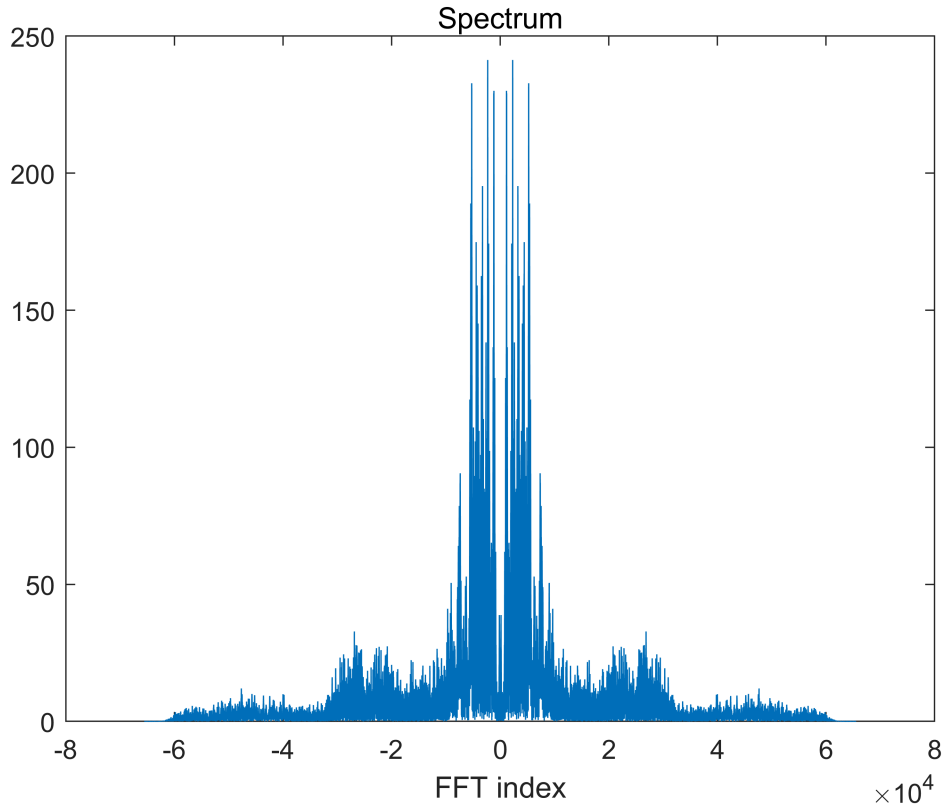
Compute Fourier transform

```
X = fft(x, Nfft);
k = 0:Nfft-1;      % FFT index

figure(1)
clf
plot(k, abs(X))
xlabel('FFT index')
title('Spectrum')
```



Center dc

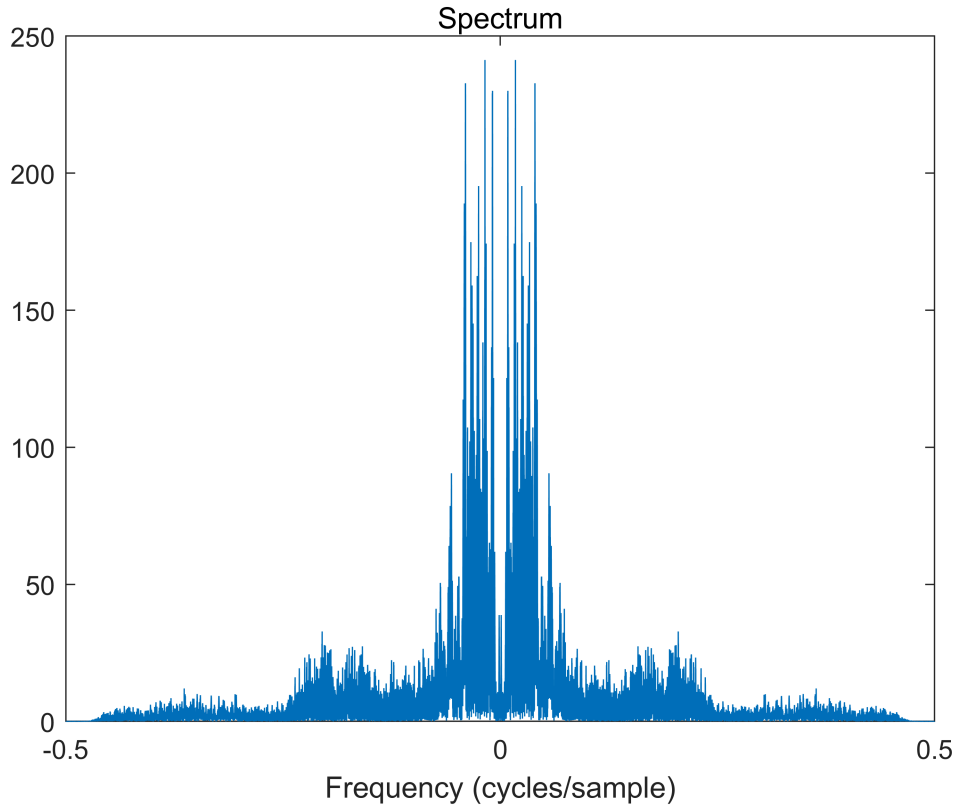
```
X2 = fftshift(X);
k2 = -Nfft/2 : Nfft/2-1;

figure(1)
clf
plot(k2, abs(X2))
xlabel('FFT index')
title('Spectrum')
```



Normalized frequency

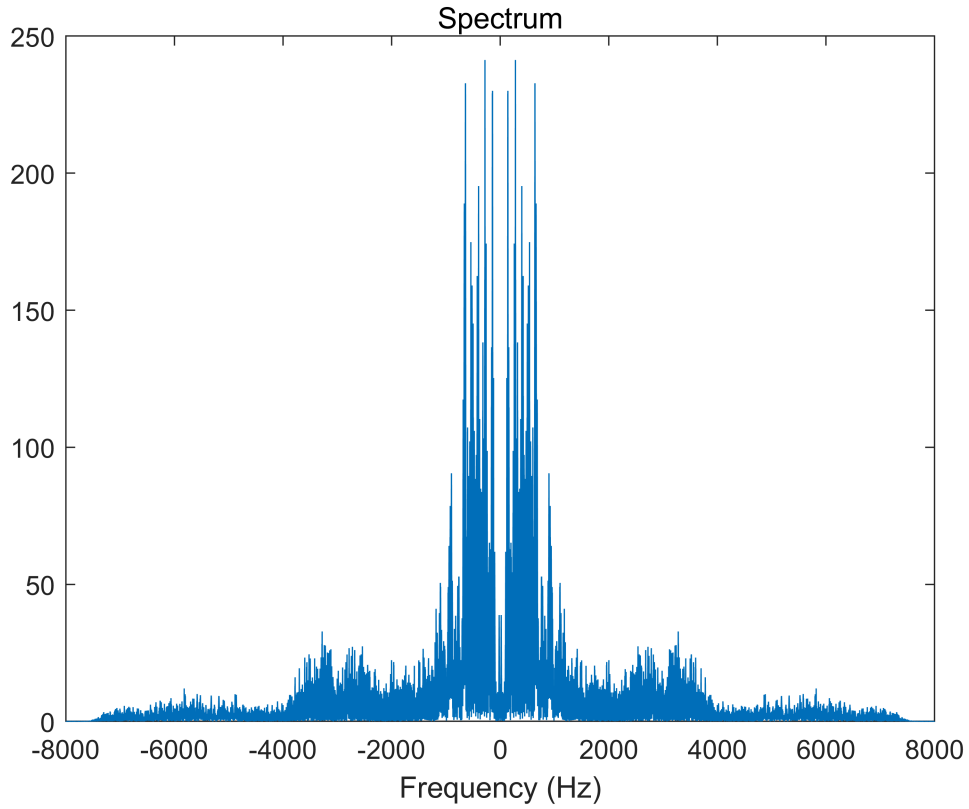
Normalized frequency is in units of [cycles per sample]

```
fn = ( -Nfft/2 : Nfft/2-1 ) / Nfft;

figure(1)
clf
plot(fn, abs(X2))
xlabel('Frequency (cycles/sample)')
title('Spectrum')
```



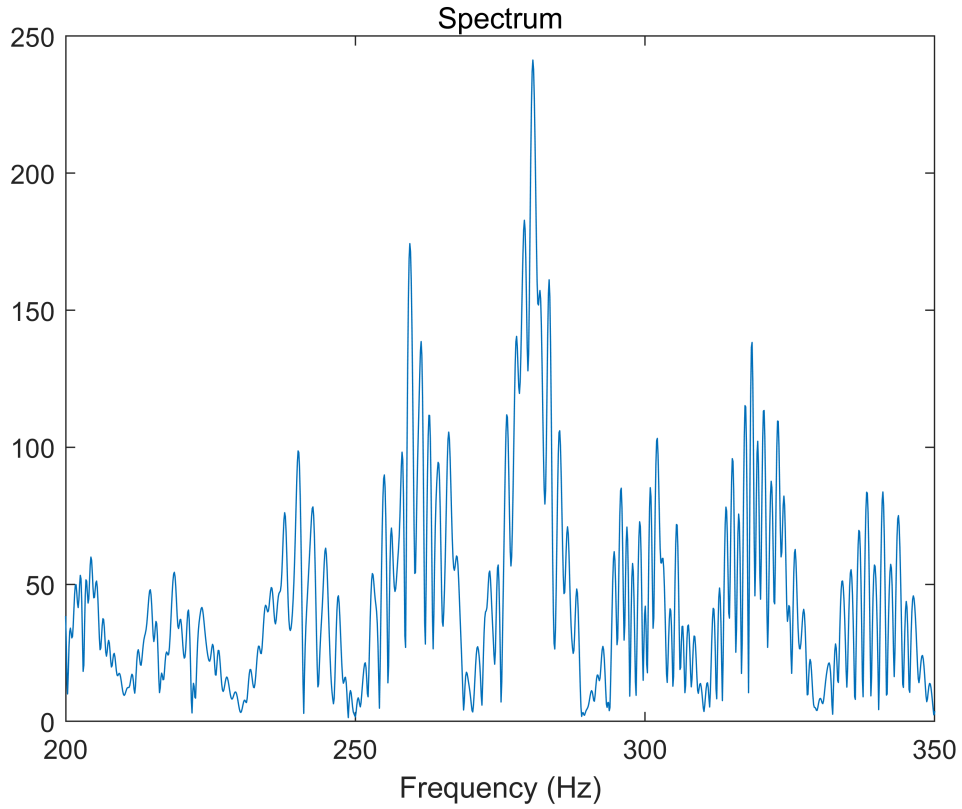
Frequency in Hz

```
f = fn * Fs;

figure(1)
clf
plot(f, abs(X2))
xlabel('Frequency (Hz)')
title('Spectrum')
```



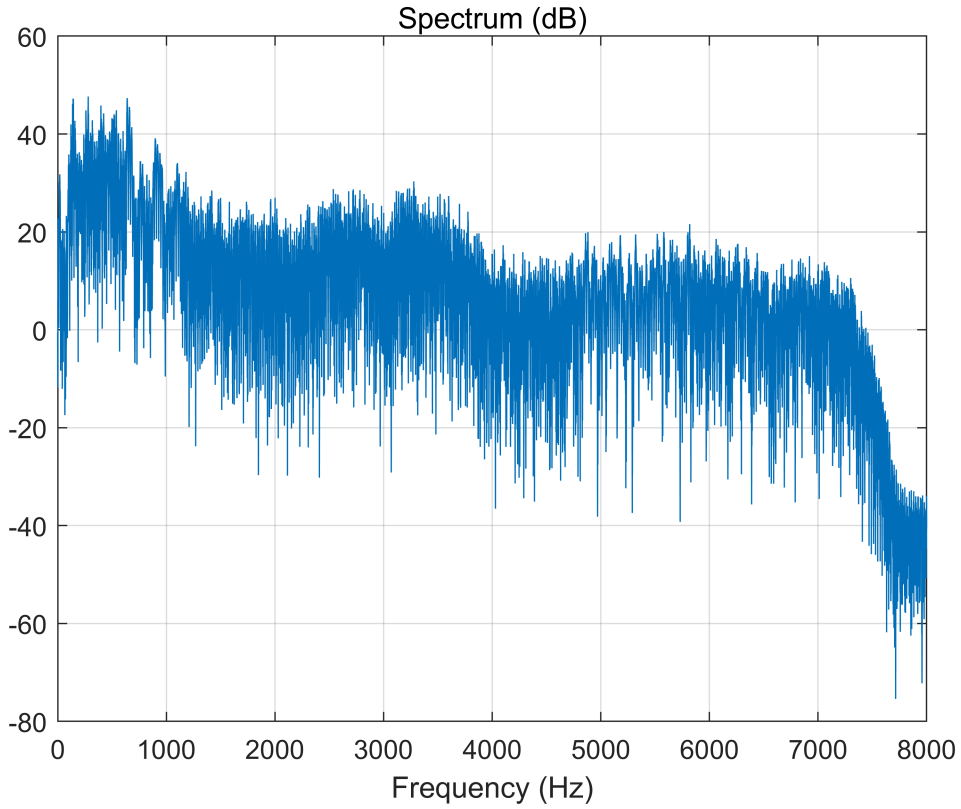
Zoom to frequency band [200 350] Hz. Notice the sidelobes

```
xlim([200 350])
```



Fourier transform in dB

```
X_dB = 20*log10(abs(X2));

figure(1)
clf
plot(f, X_dB)
xlabel('Frequency (Hz)')
title('Spectrum (dB)')

xlim([0 Fs/2])
grid
```


Spectrum (dB)
60
40
20
0
-20
-40
-60
-80
0
1000
2000
3000
4000
5000
6000
7000
8000
Frequency (Hz)