Imperial College London

DE2 Electronics 2

Tutorial 2

Lab 1 & 2 Explained

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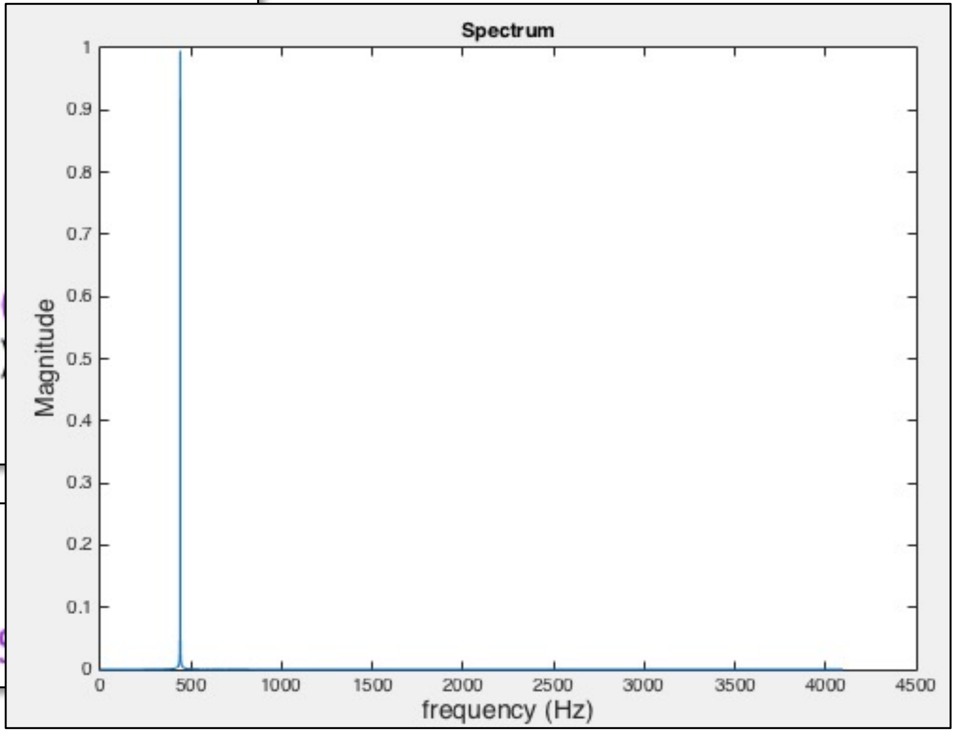
Lab 1 - Task 2: The plot_spec function

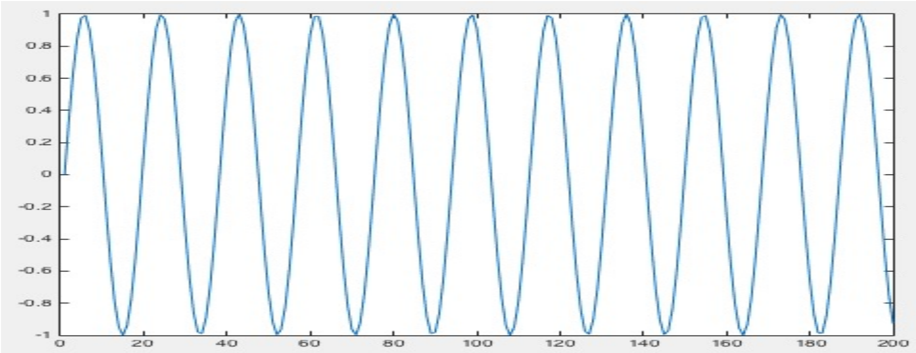
```
function plot_spec(sig, fs)

% Function to plot frequency spectrum of sig
%    usage:
%              plot_spectrum(sig, 1000)
%
% author: Peter YK Cheung, 9 Jan 2019
    magnitude = abs(fft(sig));
    N = length(sig);
    df = fs/N;
    f = 0:df:fs/2;
    Y = magnitude(1:length(f));
    plot(f, 2*Y/N)
    xlabel('\fontsize{14}frequency (
    ylabel('\fontsize{14}Magnitude')
    title('\fontsize{16}Spectrum');
```

```
>> s1 = sine_gen(1.0, 400, 10000,
>> plot_spec(s1,10000);
>> title('\fontsize{16}Amplitude S
```



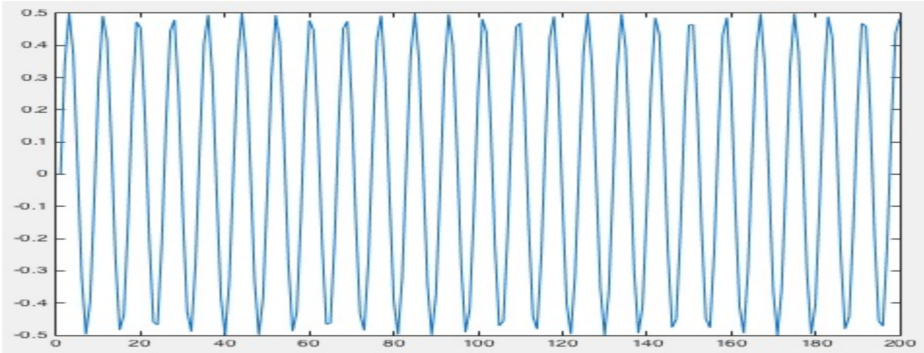
Lab 1 - Task 3: Two tones

- s1 = 440Hz sine at 1V

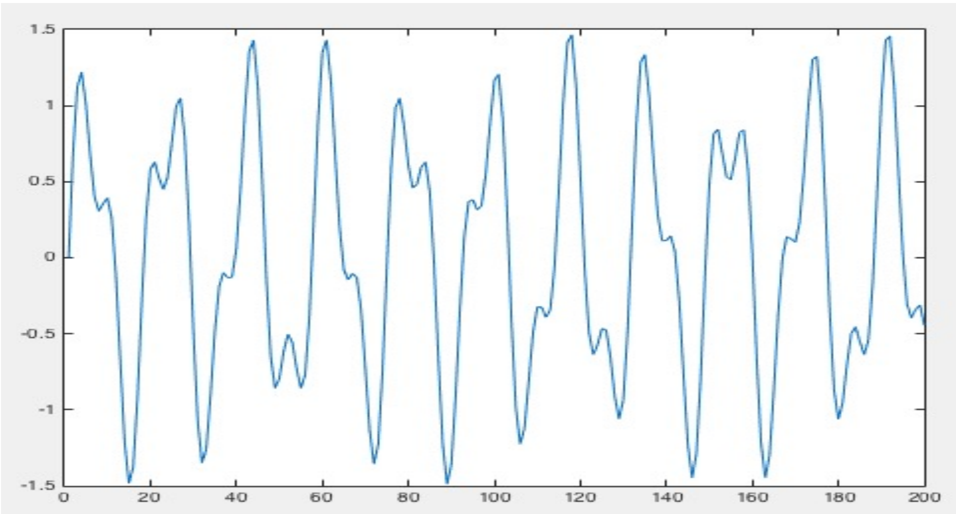


+

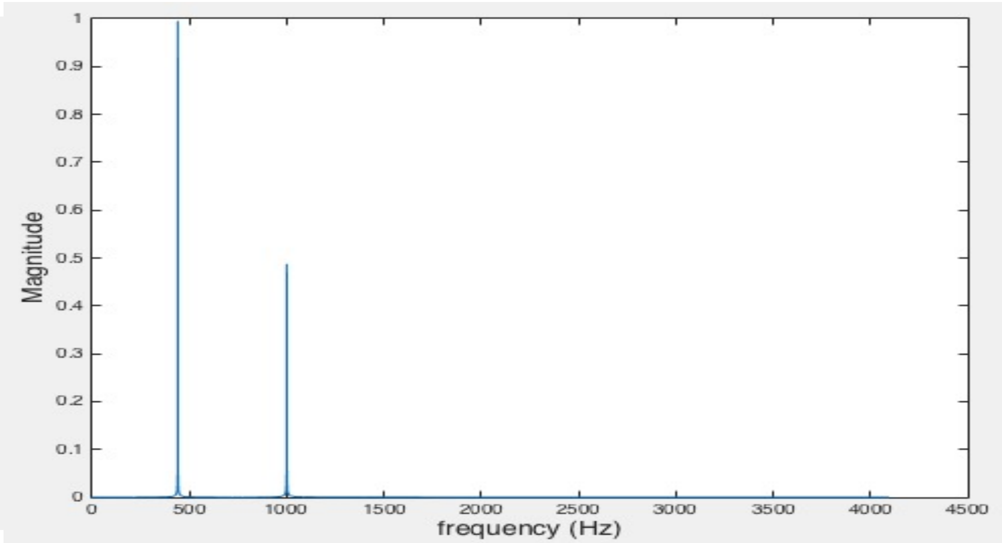
- s2 = 1kHz sine at 0.5V



- sig = s1 + s2

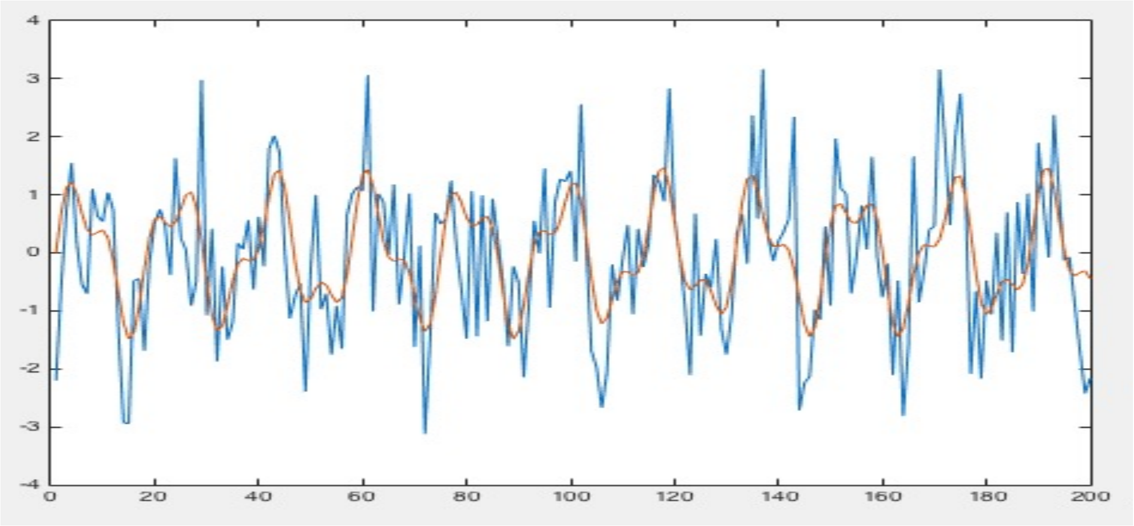


- plot_spec

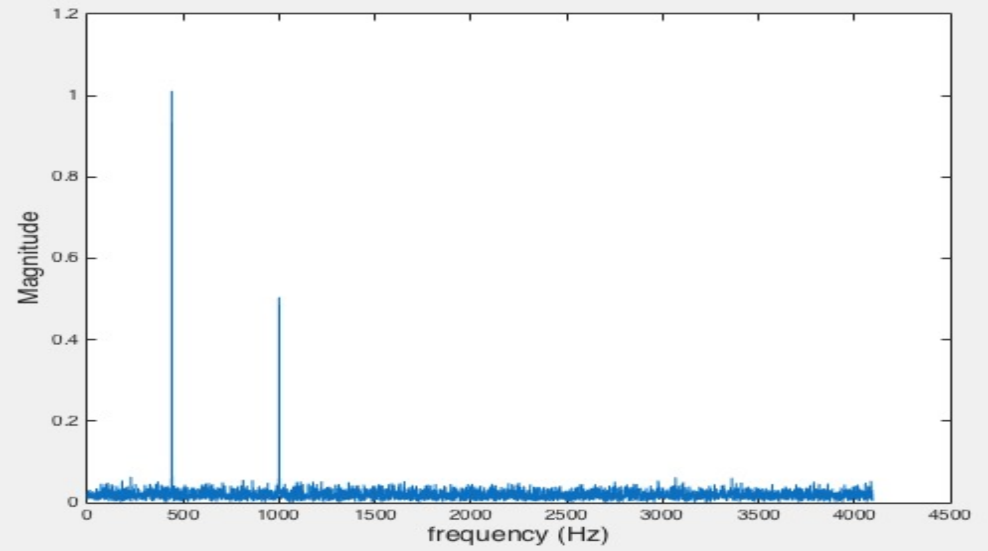


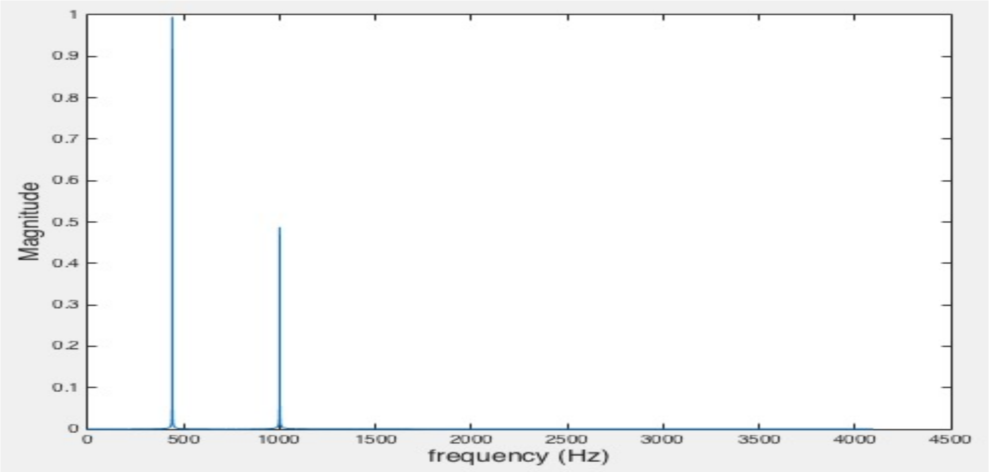
Lab 1 - Task 4: Two tones + noisy

- Noisy = sig + randn(size(sig));

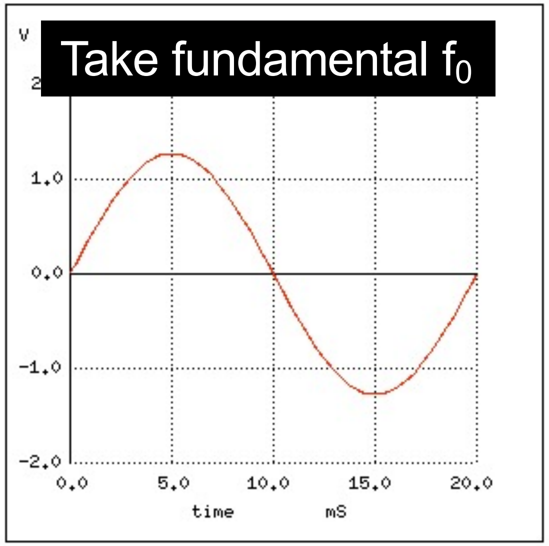


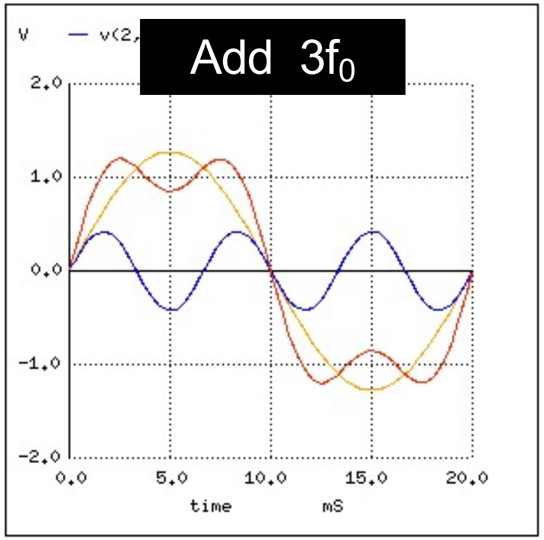
- Spectrum of noisy two tones

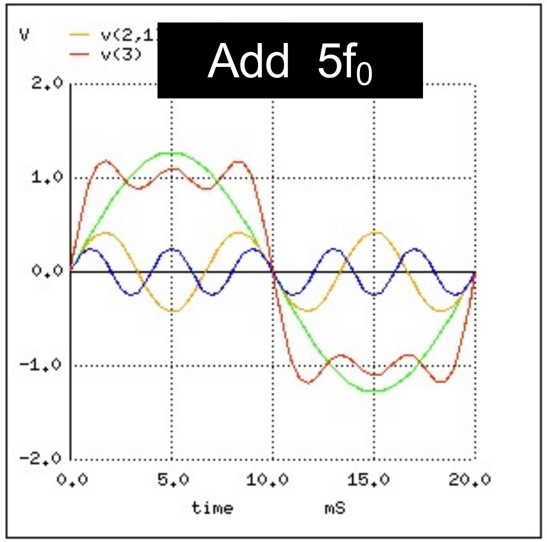


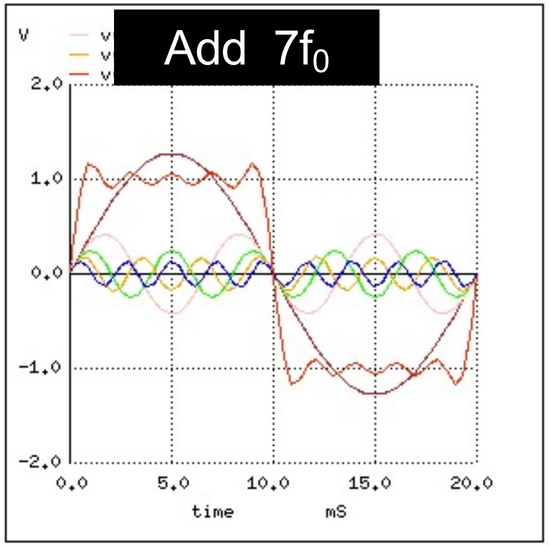


Lab 1 extra – Fourier Coefficients of square wave

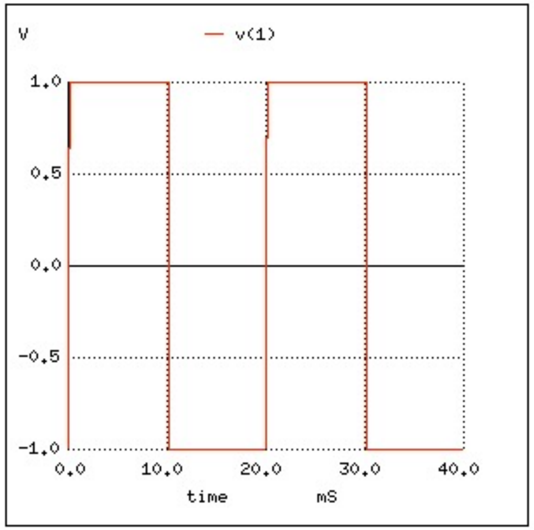








… carry on indefinitely …



PyBench Methods

PyBench.m must be in the Matlab search path

```
clear all
ports = serialportlist;       % find all serial port
pb = PyBench(ports(end));     % create a PyBench object with last port
```

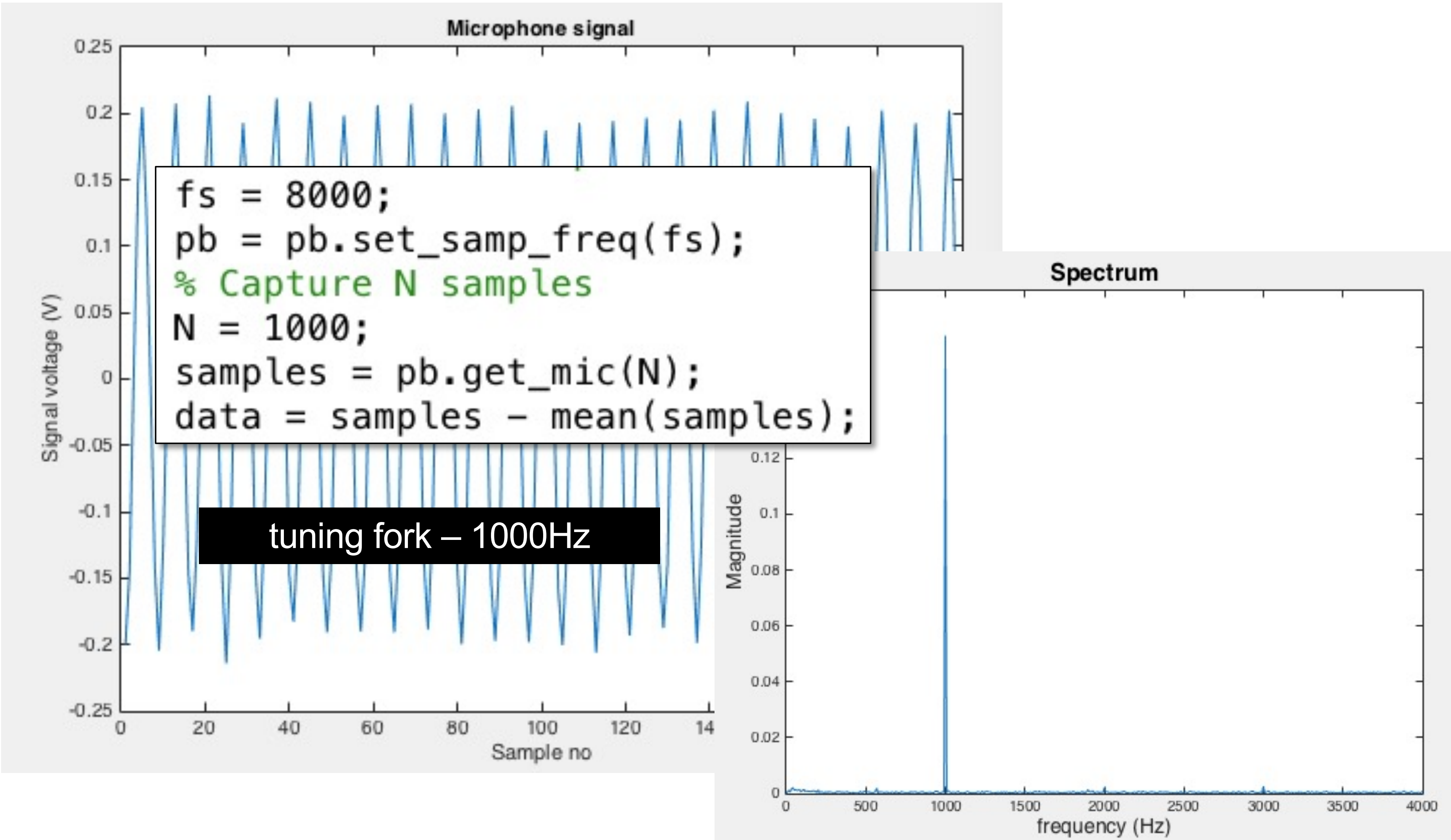
Methods	Purpose
pb.set_sig_freq (f)	Set signal frequency to f. 0.1 Hz ≤ f ≤ 3000 Hz
pb.set_samp_freq (f)	Set sampling frequency to f. 1 Hz ≤ f ≤ 30,000 Hz
pb.set_max_v (v)	Set maximum amplitude to v. 0 ≤ v ≤ 3.3
pb.set_min_v (v)	Set minimum amplitude to v. 0 ≤ v ≤ 3.3
pb.set_duty_cycle (d)	Set duty cycle of a square signal to d. 0 ≤ d ≤ 100
pb.dc (v)	Output a dc voltage v. 0 ≤ v ≤ 3.3
pb.sine ( )	Output a sinusoidal signal at set signal frequency between max_v and min_v.
pb.triangle ( )	Output a triangular signal at set signal frequency between max_v and min_v.
pb.square ( )	Output a square signal at set signal frequency between max_v and min_v, with the set duty cycle.
v = pb.get_one ()	Capture one sample v from analogue input. 0 ≤ v ≤ 3.3
data = pb.get_block (n)	Capture n samples from analogue input. 0 ≤ data ≤ 3.3
data = pb.get_mic (n)	Capture n samples from microphone. 0 ≤ data ≤ 3.3

Lab 2 Task 2 – Generate and Capture Signals

```
% Lab 2 - Task 2 - Signal generation and capture with PyBench
%
clear all
ports = serialportlist;      % find
pb = PyBench(ports(end));    % creat
% Set the various parameters
f = 440;                     % signa
fs = 8000;                   % sampl
pb = pb.set_sig_freq(f);
pb = pb.set_samp_freq(fs);
pb = pb.set_max_v(3.0);      % set m
pb = pb.set_min_v(0.5);      % set m
pb = pb.set_duty_cycle(50);
% Generate a signal
pb.sine();
```

```
% Capture N samples
N = 1000;
samples = pb.get_block(N);
data = samples - mean(samples);
% plot data
figure(1);
plot(data(1:200),'o');
hold on
plot(data(1:200));
xlabel('Sample no');
ylabel('Signal voltage (V)');
title('Captured signal');
hold off
% find spectrum
figure(2);
plot_spec(data,fs);
```

Lab 2 Task 3 – Microphone signal




```
fs = 8000;
pb = pb.set_samp_freq(fs);
% Capture N samples
N = 1000;
samples = pb.get_mic(N);
data = samples – mean(samples);
```

Lab 2 Task 3 – Repeated capture & plot spectrum

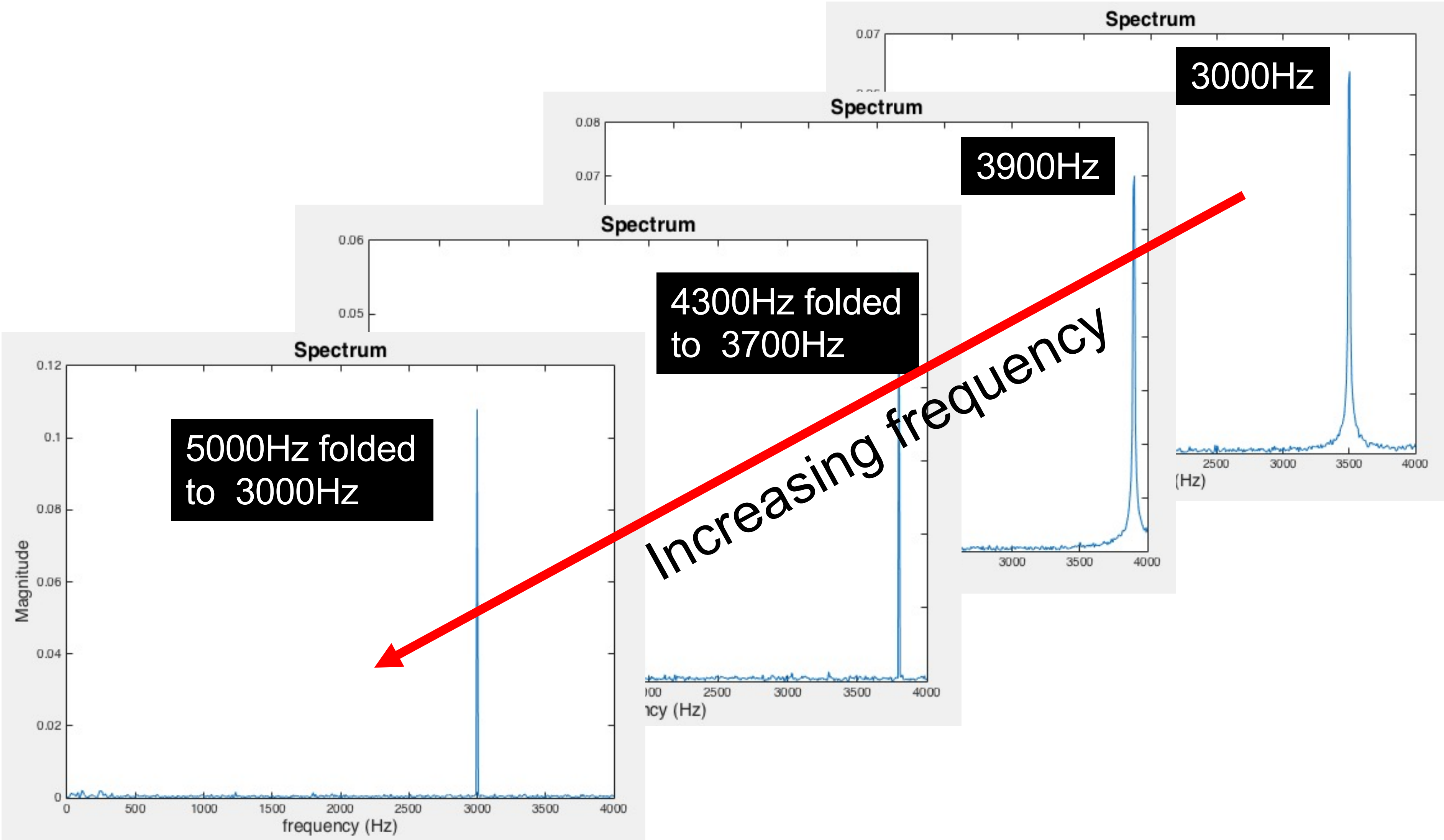
```
% repeat capture and plot spectrum
while true
    samples = pb.get_mic(N);
    data = samples - mean(samples);
    figure(2)
    clf;
    plot_spec(data,fs);
end
```

Warning: Running Matlab in an infinite loop may prevent you from re-gaining control over Matlab or even your computer. There are two things you may try if you want to get back control: 1) Type CTRL+C in the Command Window to interrupt Matlab; 2) kill the Matlab process and restart it again.

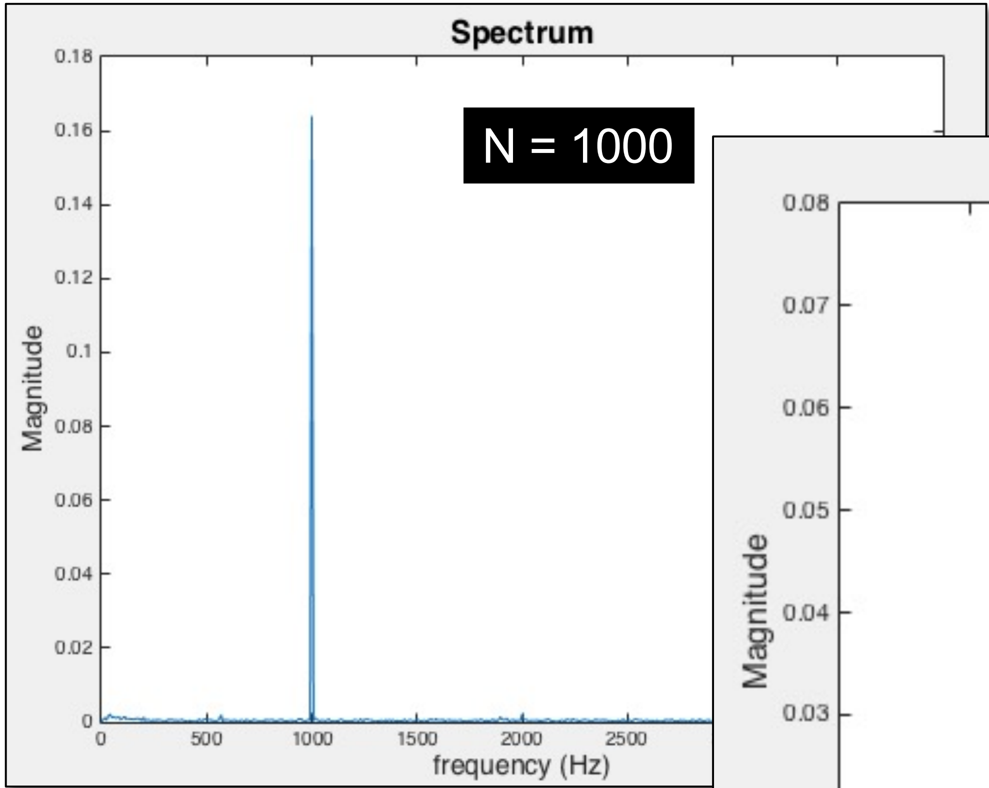
Recover from lost of serial communication:

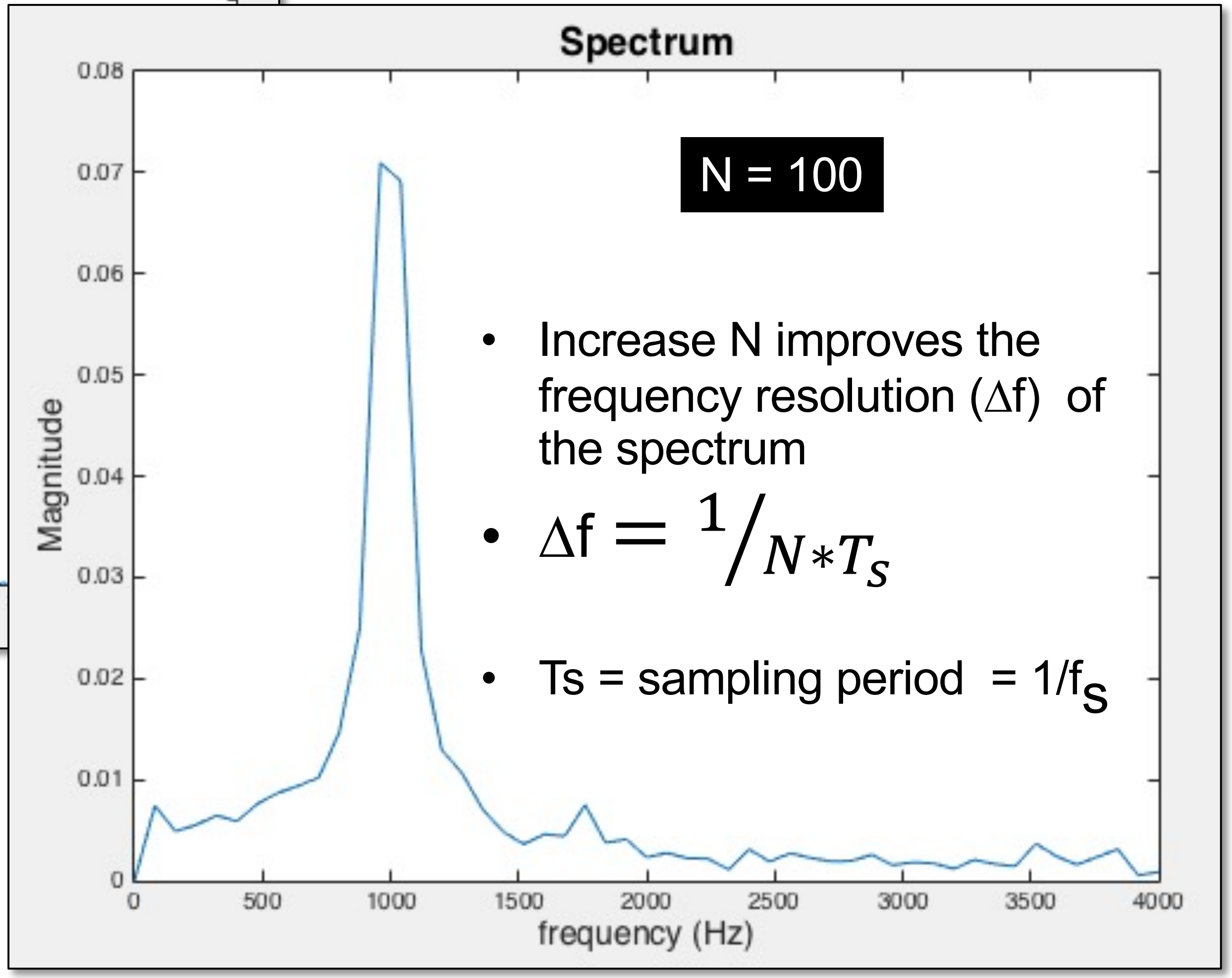
1. Disconnect/reconnect USB; kill & restart Mablab
2. CTRL+C in command window, then type fclose(pb.usb) to shut down usb communication port

Lab 2 Task 3 – Demonstrate spectral folding (aliasing)



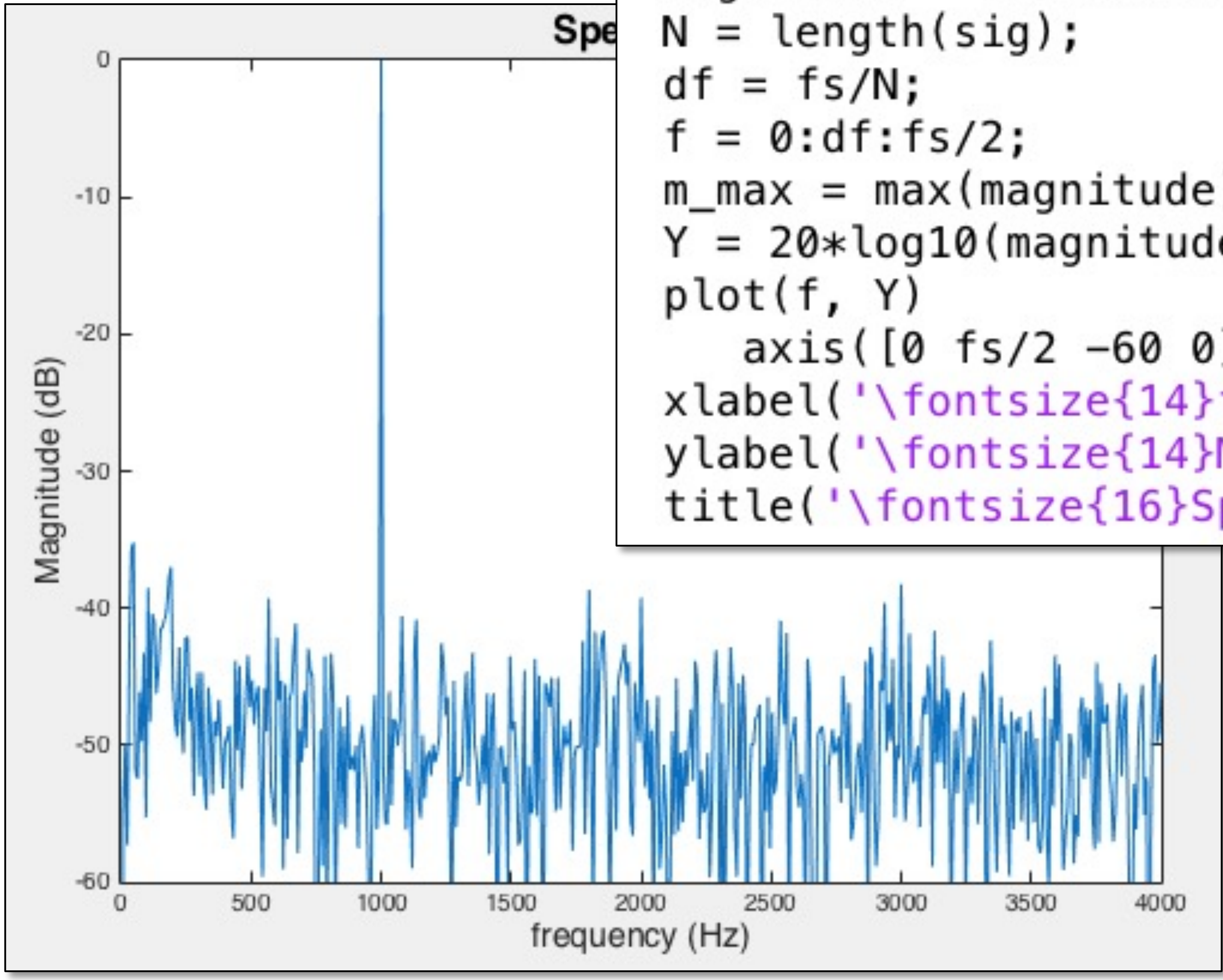
Lab 2 Task 3 – Effect of changing N – no of samples to analyse





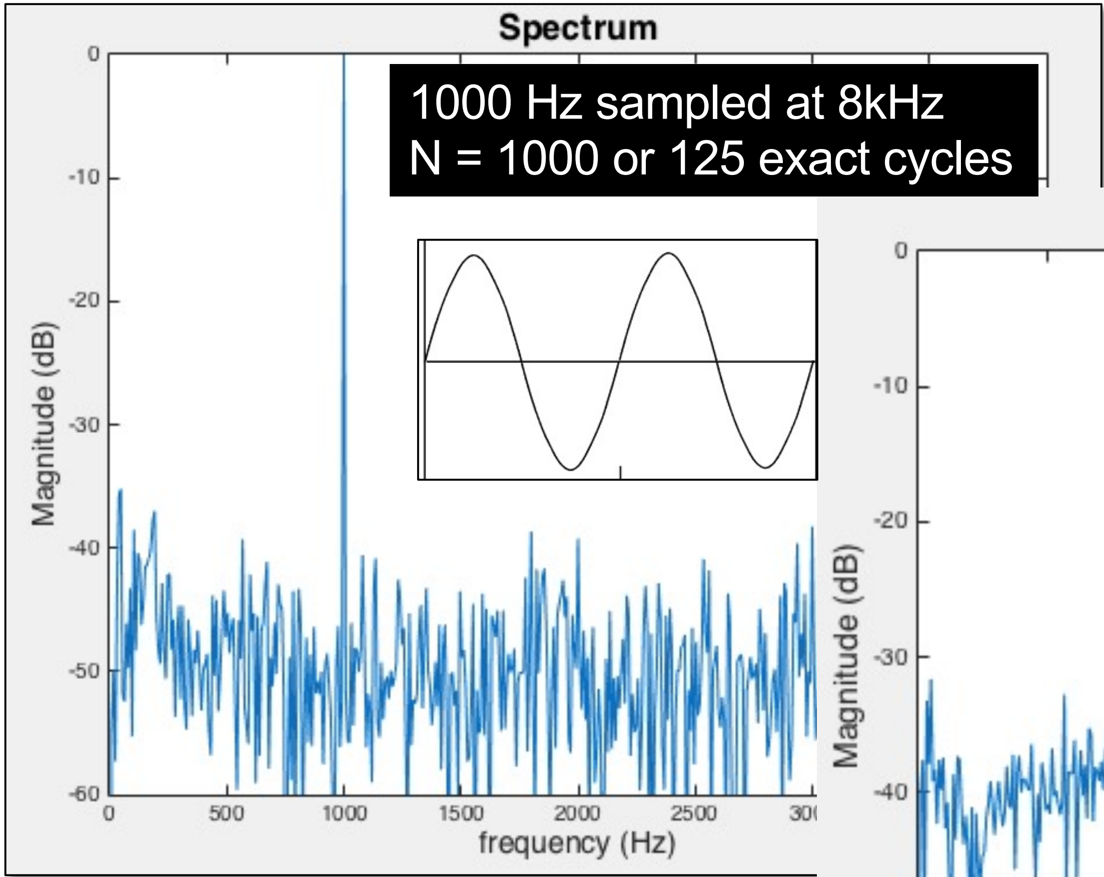
- Increase N improves the frequency resolution (Δf) of the spectrum
- $\Delta f = {}^{1}/_{N * T_S}$
- Ts = sampling period = $1/f_S$

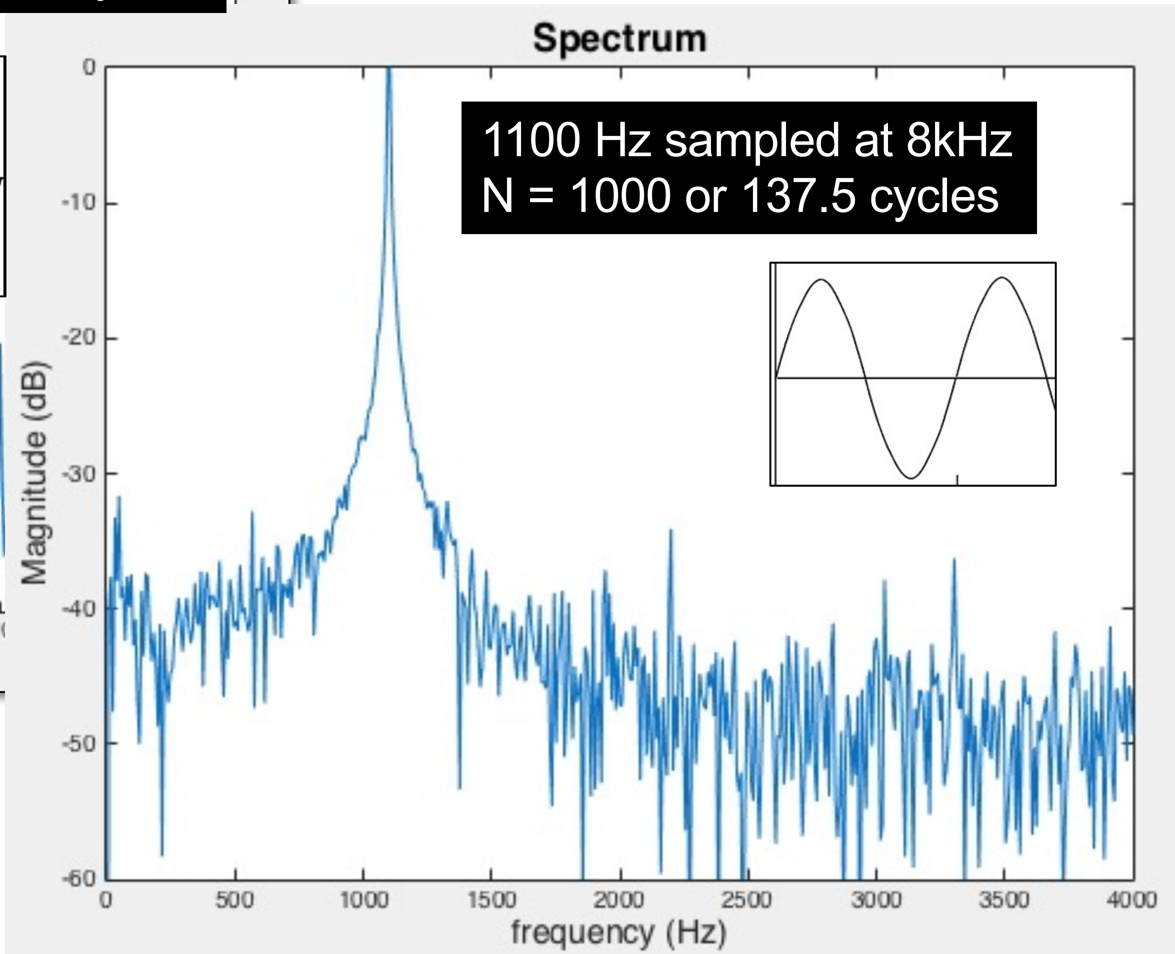
Lab 2 Task 4 – Magnitude in dB



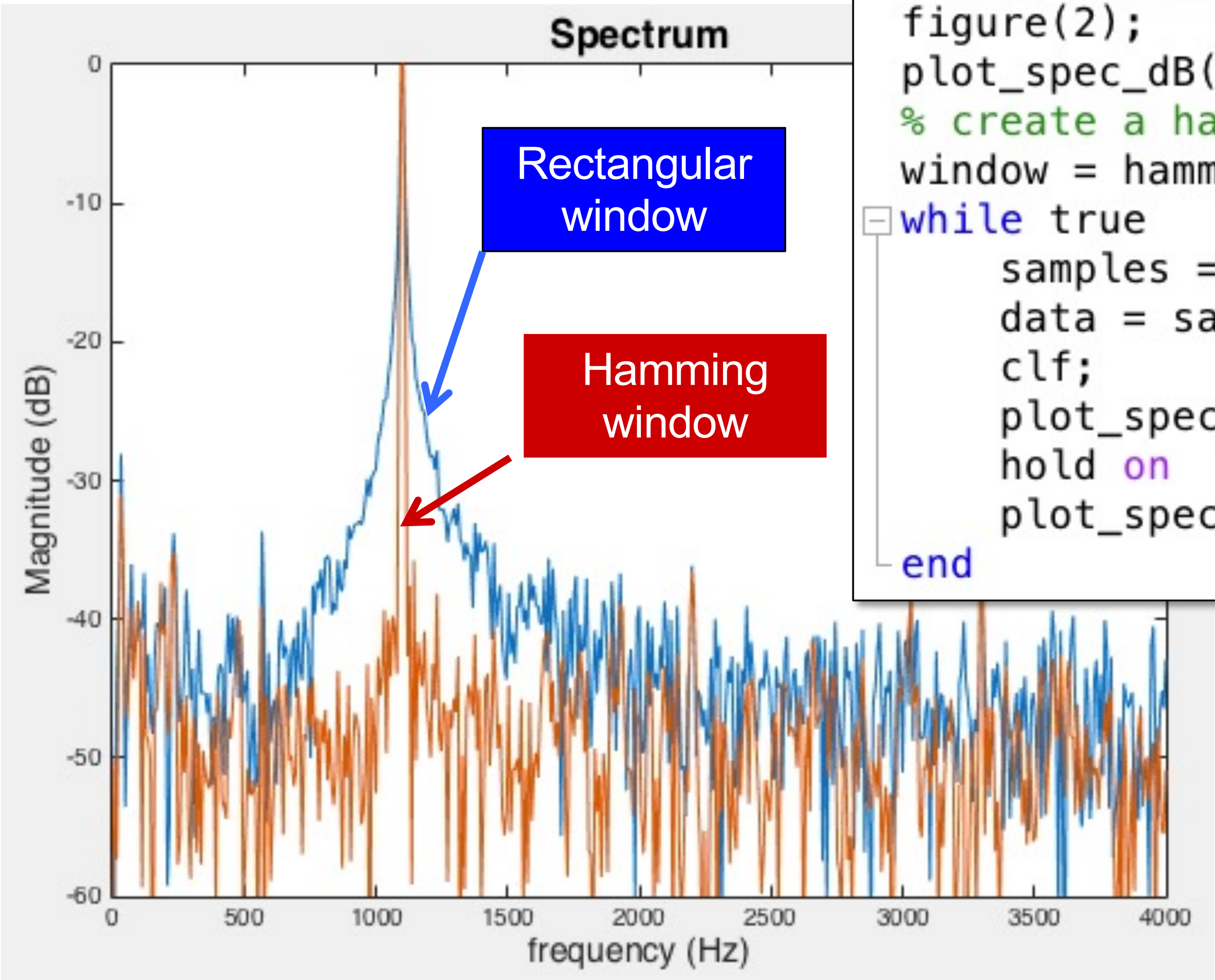

```
magnitude = abs(fft(sig));
N = length(sig);
df = fs/N;
f = 0:df:fs/2;
m_max = max(magnitude);
Y = 20*log10(magnitude(1:length(f))/m_max);
plot(f, Y)
   axis([0 fs/2 -60 0]);
xlabel('\fontsize{14}frequency (Hz)')
ylabel('\fontsize{14}Magnitude (dB)');
title('\fontsize{16}Spectrum');
```

Lab 2 Exercise 4 – Windowing effect





Lab 2 Task 4 – Rectangular vs Hamming Window




```
% find spectrum
figure(2);
plot_spec_dB(data,fs);
% create a hamming window
window = hamming(length(data));
while true
    samples = pb.get_mic(N);
    data = samples - mean(samples);
    clf;
    plot_spec_dB(data,fs);
    hold on
    plot_spec_dB(data.*window,fs);
end
```

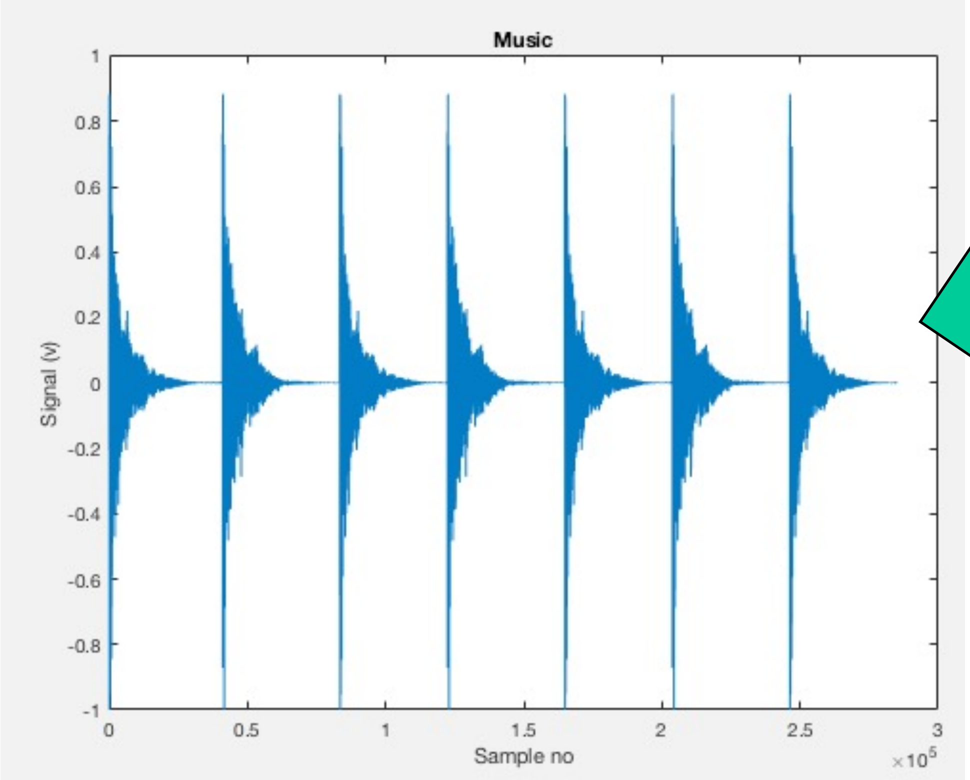
Lab 2 Task 5 – Calculate energy in 20ms segment

$$\sum_{i=1}^{N} x^2(t)$$ where N is the number of samples in 20ms

```
% Divide signal into se
T = 0.02;          % divid
N = fs*T;          % for t
E = [];
for i=1:N:length(sig)-N+1
    seg = sig(i:i+N-1);
    E = [E seg'*seg];
end
% plot the energy graph and the peak values
figure(2);
clf;
x = 1:length(E);
plot(x, E)
xlabel('Segment number');
ylabel('Energy');
hold on
% Find local maxima
[pks locs] = findpeaks(E);
plot(locs, pks, 'o');
hold off
% plot spectrum of energy
figure(3)
plot_spec(E - mean(E), 1/T);
```

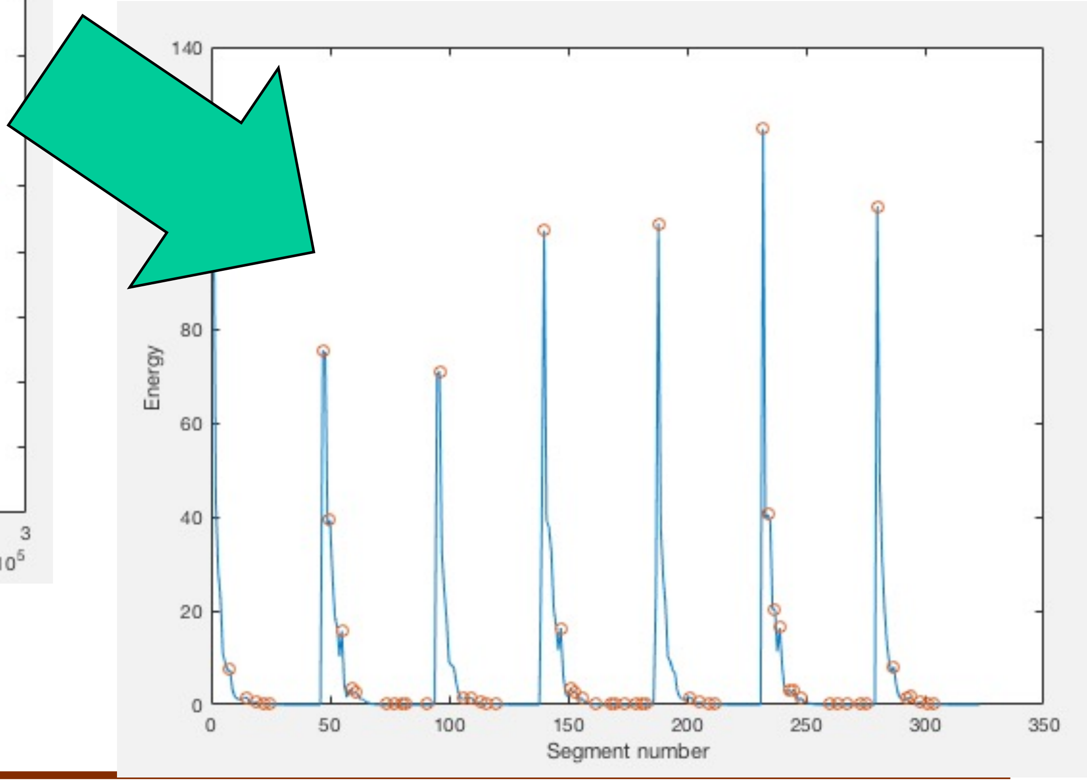
Lab 2 Task 5 – Analyse beat of drum beats (1)

$$\sum_{i=1}^{N} x^2(t)$$ where N is the number of samples in 20ms



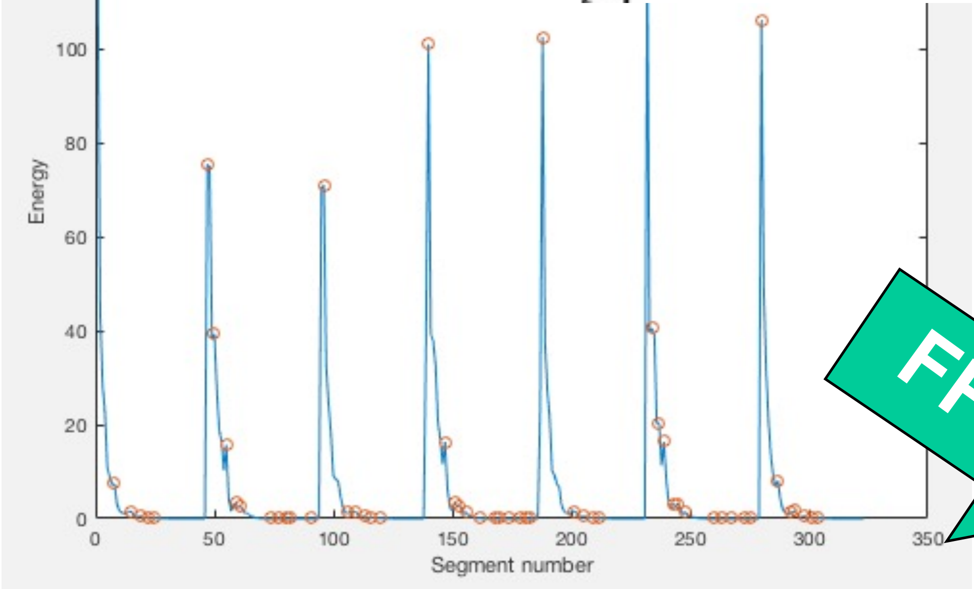
Signal x(t)

Energy of signal

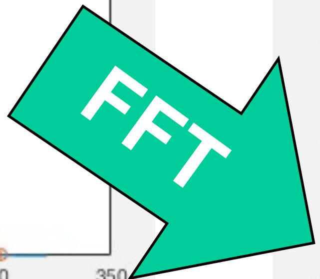


Lab 2 Task 5 – Analyse beat of drum beats (2)

$$\sum_{i=1}^{N} x^2(t)$$ where N is the number of samples in 20ms



Energy vs time



Spectrum of energy