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EE4820: Biomedical Signal Processing
Problem Set 2: Reducing Ensemble Noise

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Due Mon. 02/07

1. List at least 3 potential sources of noise in these neural recordings.

2. Describe how ensemble averaging helps as a signal processing method by filling in the blanks:

   Ensemble averaging increases the ___*SNR*___ by a factor of _____.
   (where n is the number of trials or observations)

   Then briefly outline the mathematical derivation of this statement.

3. Semmlow P2.3

4. Semmlow P2.4

5. Semmlow P2.9

6. Ensemble average MATLAB lab exercise

   - Start MATLAB.
   - Change directories to the folder in which you stored the data files (Use the *cd* command or use the drop down dialog box labeled *Current directory* at the top of the Matlab window).
     - *OR* you can add a directory to the path: *File → Set Path → Add directory.*
       Choose the folder in which the data files are saved.
       → OK
       → Save
       → Close.

   - Load the file by typing:

     `load verg1;`

   - See what data you have loaded by typing

     `whos`

- This data contains eye positions during a saccade; i.e., the eye was focusing on an initial target. Then the target suddenly moves, and the eye moves quickly toward the new target.

- The eye position in response to this sudden change in stimulus position is like a step response.

- Data was collected on 47 trials at a 200Hz sampling rate. Each trial was 2s long, with the recording beginning 100ms before the stimulus.

(a) Using an ensemble average, plot the average step response.

(b) Also, determine the 10-90% rise time.

1. List at least 3 potential sources of noise in these neural recordings.

3 potential sources of noise are pink noise, white noise, and thermal noise.

In "Rhythms of the Brain", stated high concentration of ions such as potassium (K^+) and chloride (Cl^-) keep other ions from entering. Where the interaction of the ions creates some voltage. Creating a "spike" when recording the body reading.

2. Describe how ensemble averaging helps as a signal processing method by filling in the blanks:

   Ensemble averaging increases the ___SNR___ by a factor of ___$\sqrt{N}$___.
   (where n is the number of trials or observations)

   Then briefly outline the mathematical derivation of this statement.

3. Semmlow P2.3

2.3   Use Equation 2.14 to *analytically* determine the RMS value of a "square wave" with an amplitude of 1.0 V and a period 0.2 s.
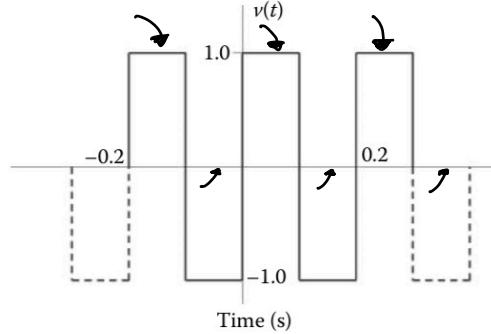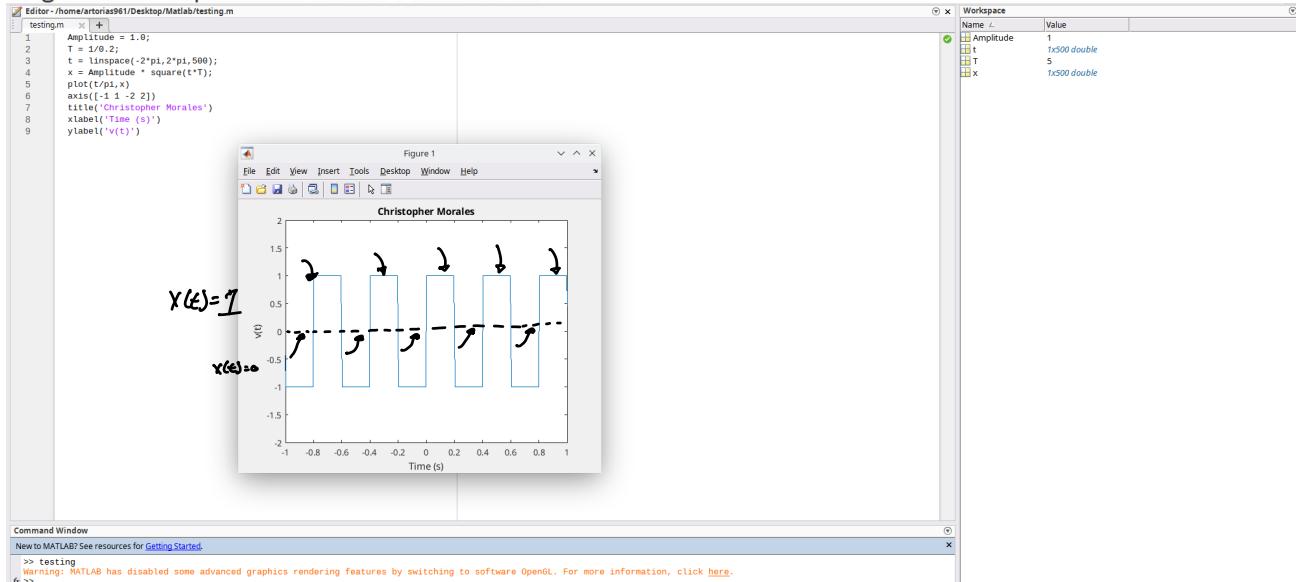

Figure P2.3   Square wave used in Problem 2.3.
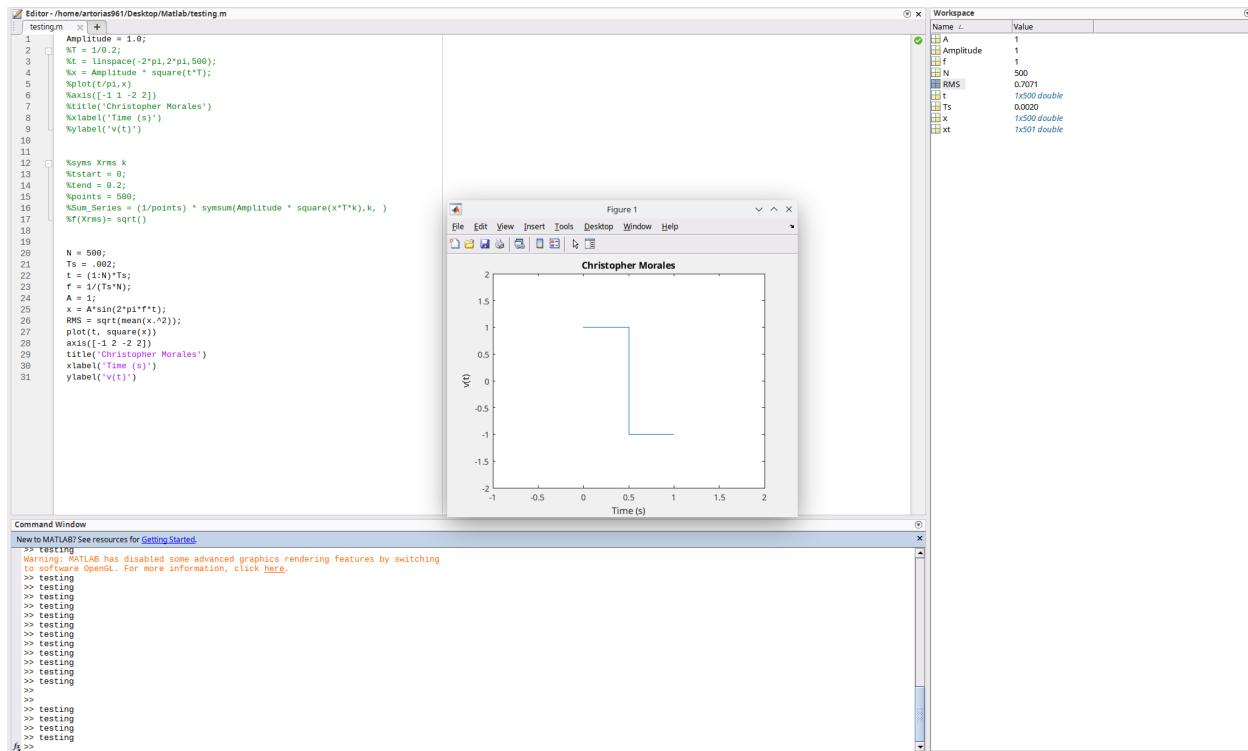
$$\bar{X}(t)_{rms} = \left[\frac{1}{T}\int_0^T x(t)^2\, dt\right]^{1/2} = \frac{1}{0.2}\int_0^{0.2}(1)^2\, dt = 0.2\frac{1}{2}\,(0.2-0) = \frac{1}{0.2}(0.2) = 1$$

$$T = 0.2$$

4. Semmlow P2.4

2.4 Generate one cycle of the square wave similar to the one shown above in a 500-point MATLAB array. Determine the RMS value of this waveform using Equation 2.13. [Hint: When you take the square of the data array, be sure to use a period before the up arrow so that MATLAB does the squaring point-by-point (i.e., x.^2).]

5. Semmlow P2.9

2.9 If a signal is measured as 2.5 V and the noise is 28 mV (28×10^{-3} V), what is the SNR in dB?

$$SNR_{dB} = 20 \, log_{10}(SNR) = 20 \, log_{10}\left(\frac{\sigma_s}{\sigma_n}\right) = 20 \, log_{10}\left(\frac{2.5}{0.028}\right) = 39.01563 \approx 39 \, dB$$

$$SNR = \frac{\sigma_s}{\sigma_n}$$
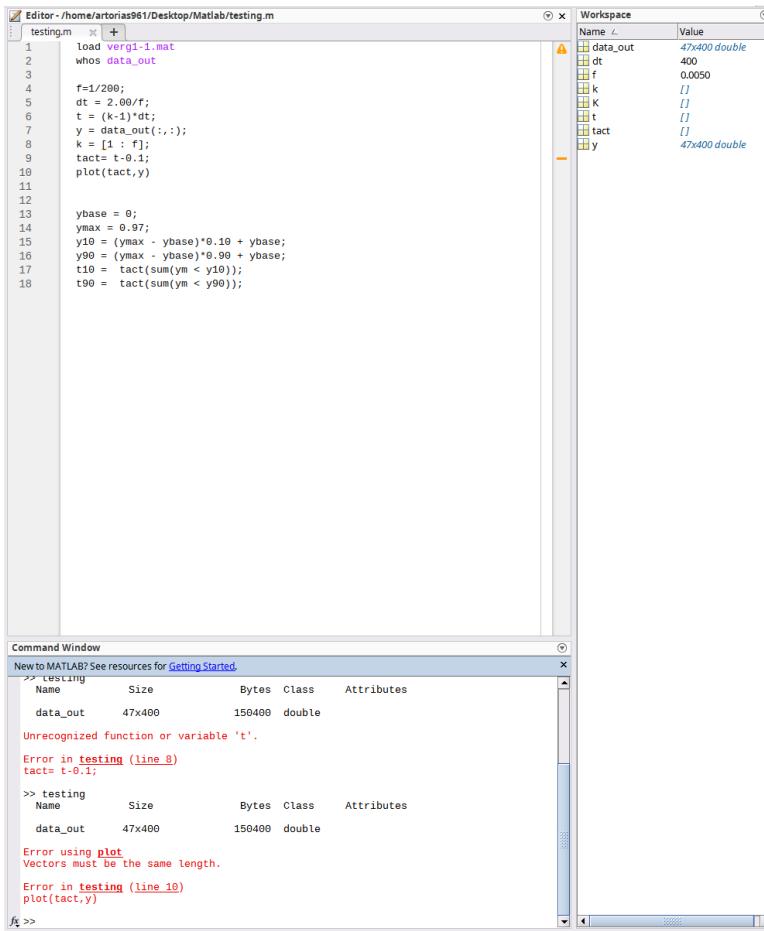
$$\sigma_s = 2.5V$$

$$\sigma_n = 28mV = 0.028V$$

6. Ensemble average MATLAB lab exercise

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     ```

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(a) Using an ensemble average, plot the average step response.

(b) Also, determine the 10-90% rise time.


```
Editor - /home/artorias961/Desktop/Matlab/testing.m
testing.m
1     load verg1-1.mat
2     whos data_out
3
4     f=1/200;
5     dt = 2.00/f;
6     t = (k-1)*dt;
7     y = data_out(:,:);
8     k = [1 : f];
9     tact= t-0.1;
10    plot(tact,y)
11
12
13    ybase = 0;
14    ymax = 0.97;
15    y10 = (ymax - ybase)*0.10 + ybase;
16    y90 = (ymax - ybase)*0.90 + ybase;
17    t10 =  tact(sum(ym < y10));
18    t90 =  tact(sum(ym < y90));
```

Workspace

Name	Value
data_out	47x400 double
dt	400
f	0.0050
k	[]
K	[]
t	[]
tact	[]
y	47x400 double

```
Command Window
New to MATLAB? See resources for Getting Started.
>> testing
    Name          Size              Bytes  Class     Attributes

    data_out      47x400            150400  double

Unrecognized function or variable 't'.

Error in testing (line 8)
tact= t-0.1;

>> testing
    Name          Size              Bytes  Class     Attributes

    data_out      47x400            150400  double

Error using plot
Vectors must be the same length.

Error in testing (line 10)
plot(tact,y)

fx >>
```

Im unsure what the error means but my idea is to get the average of each column then plot it with the sample

We know the time shift by 0.1s so we shifted

Then by eye balling we are + $\int$ y10 and 90 to get an estimate value