

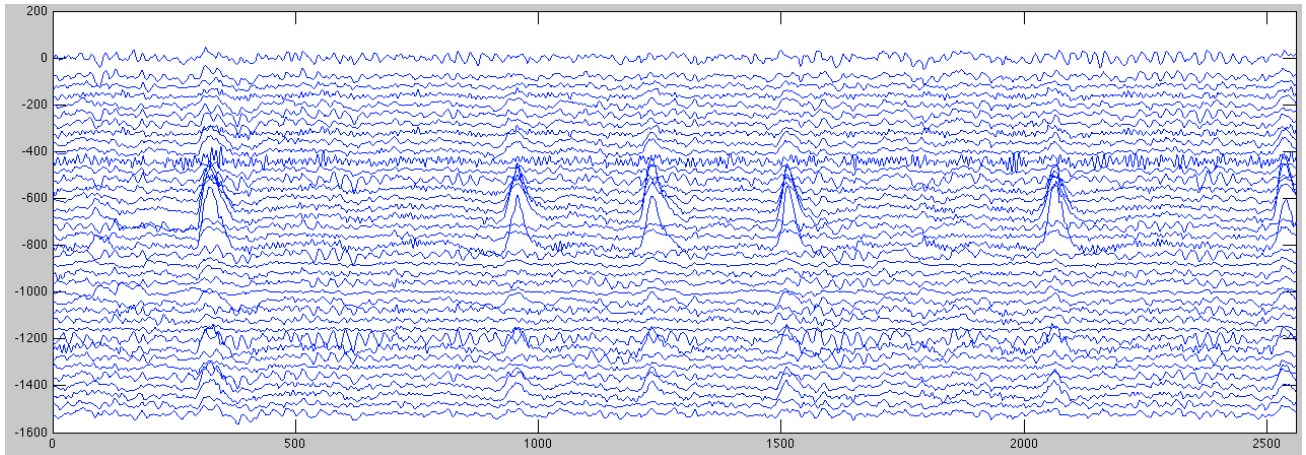
Question 1 – artifacts, noise, differential recording, spectral analysis:

Download the file

<http://www.brainmapping.org/NITP/PNA/tests/PNIAMidtermData2010.mat> and load it into matlab (>>> load PNIAMidtermData2010.mat)

This file has within it a matrix, s , containing 39 channels of real eeg for a single 10 sec epoch

- A) Use matlab to make a single plot of the signal in all 39 channels. Shift the Y values by 40 (arbitrary units), for a result analogous to the following (yours will *definitely* look different):



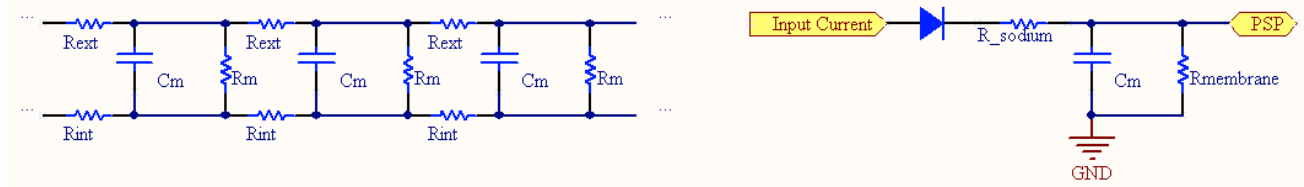
Send your plot.

- B) The segment you are viewing is contaminated severely by artifact. Explain the most likely source of this artifact, and the physics behind how it couples into this EEG record. Fourier analysis may help. Is the signal near 10 Hz likely to be noise?
- C) In the record you have downloaded, the potential at each electrode was compared to a common reference (in this case the average potential on the right leg) to form each of the channels that are the columns of s . In the clinic, a different montage frequently is used, in which the channels are formed by computing the difference between adjacent electrodes.

Assume that the physical electrodes are arranged such that adjacent columns in s are adjacent electrodes. I.e., $s(:,2)$ and $s(:,3)$ are the signals from two adjacent electrodes. Form a clinical style array, m , where whose 38 columns are the difference in signal between adjacent electrodes in s . I.e., $m(:,4)$ is constructed as the difference between $s(:,4)$ and $s(:,5)$. Plot these results as above and *send the plot*. Explain these results.

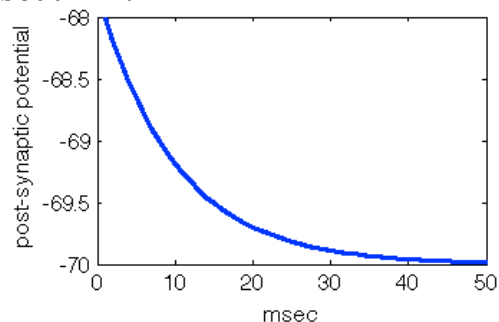
Question 2: modeling, convolution, neurophysiology.

Early on, we presented an electrical neuron membrane model consisting of resistive and capacitive elements as in the figure on the left, below:



(For completeness, the figure on the right is a lumped element model that models the *epsp* a bit better.)

We can make a simplified model of an *epsp* as the voltage response of the membrane to a pulse of amplitude, A : $v(t) = \text{epsp} = Ae^{-t/\tau}$, where τ is the membrane time constant, dominated by its resistance and capacitance. For neurons, τ is about 10 ms. A single *epsp* event displaces the membrane potential by about 2 mV:



For an action potential to be formed, the membrane potential of a postsynaptic cell must be increased by about 15 mV.

A) Estimate the rate at which *epsp*'s must be created in the post-synaptic cell in order for the post-synaptic cell to reach threshold, assuming that each input event creates simultaneous *epsp*'s at two adjacent synapses, creating an effective 4 mV *epsp*. You can use convolution (*cf.* <http://www.brainmapping.org/NITP/PNA/Readings/NeuronFunction+AnatomyNITP.pdf>, "Spatiotemporal summation of psp's") to solve this. The code below may help you get started:

```
resting_potential = -70; % mV
threshold = resting_potential + 15; % action potential threshold
res = 0.1; % Time resolution in msec
tau=10/res; % in units of 0.1 msec
t=0:1:50/res; % 50 msec model
impulse_response = exp(-t./tau); % post-synaptic cell impulse response
epsp = 4 * impulse_response; % 4 mV epsp
input = [1, zeros(1,(100/res)-1)]; % one pulse in 100 ms;
psp = resting_potential + conv(input, epsp); % resulting post-synaptic potential
time_axis = res:res:length(psp)*res;
plot(time_axis, psp, 'linewidth', 2); % about 4 mV more positive
set(gca, 'XLim', [0, 50]); % window dressing
xlabel('microsec');
ylabel('post-synaptic potential');
```

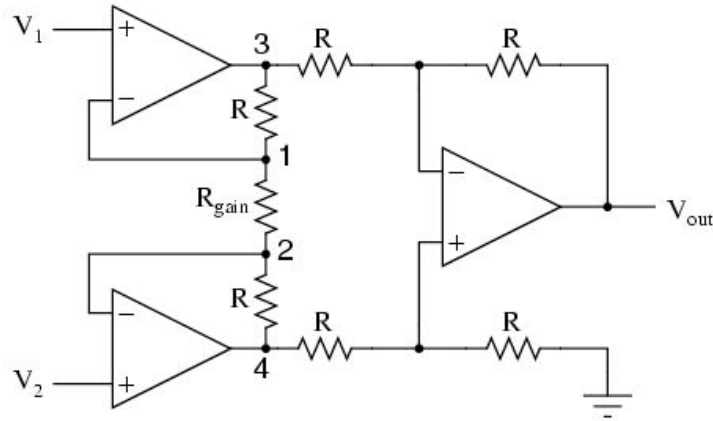
When the post-synaptic potential (psp) is greater than threshold, an AP will be formed.

B) It is unusual for cortical neurons to fire at rates greater than about 200 Hz. How can post-synaptic cells reach thresholds with typical inputs (2 mV *epsp*'s)?

Question 3 - Circuit analysis

In the circuit below, show that the gain, G , is:

$$G = \frac{V_{out}}{v_1 - v_2} = 1 + \frac{2R}{R_{gain}}$$



Question 4: distortion, linearity, noise

Huan and Mahsa created a new device intended to detect very low level signals by their phase modulation at a fixed frequency of 308 kHz. They sent it out to Madeleine who reported that, when observing the signal output at 308 kHz, she noted a component about 20 dB lower in amplitude at a frequency of somewhat over 600 kHz. Huan was concerned, and said that this was an obvious sign that the device was not behaving linearly (why?). Mahsa felt that it was highly unlikely that the circuit she had herself designed was adding distortion and suggested that there were other more likely explanations (name at least two) and that, in any case, the extra spectral component was inconsistent with a distortion process (please give an argument in support of that claim). What simple experiment could they do to quickly resolve this question?