Neuroengineering 2024-2025

Exam 10 September 2025

Part II

How to submit your answers.

The answers can be typed in the provided text file, following the template. Do not modify or move the lines containing the headers.

Keep your answers tidy. Messy, hard-to-read answers may penalize your mark.

The maximum total score for part II is **8**.

Carefully read the following text and answer the questions listed below.

A clinical research team is designing an experiment to study the N100, an auditory Event-Related Potential (ERP). The goal is to establish a baseline measure of sensory processing speed in a group of healthy volunteers. The N100 component in this type of experiment typically has a peak amplitude of 5 µV at the scalp. The background spontaneous EEG is expected to have a standard deviation (and thus an RMS value) of 15 µV. The team has drafted the following protocol for data acquisition and analysis.

Hardware Specifications

Electrodes: EEG data will be acquired using non-polarizable Silver/Silver-Chloride (Ag/AgCl) electrodes. The montage will consist of a single recording electrode placed at the Cz position of the International 10-20 System and reference electrodes on both mastoids (A1 and A2), which will be physically shorted together (linked-mastoid reference).

Analog Subsystem: The signals will be fed into a single-channel biosignal amplifier with a differential gain of 80 dB and a Common-Mode Rejection Ratio (CMRR) of 90 dB. During the recording, a 50 Hz powerline noise artifact with a peak amplitude of 150 mV is present as common-mode interference. The amplifier includes an analog band-pass filter with cutoff frequencies set at 0.5 Hz and 85 Hz.

Digital Subsystem: The amplified and filtered analog signal is digitized by an Analog-to-Digital Converter (ADC). The ADC has a resolution of 16 bits and a symmetric input voltage range of ±5 Volts. The sampling frequency (f_s) is fixed by the device at 128 Hz.

Experimental Protocol

Stimulation: Subjects will be seated in a sound-attenuated room and will listen to a series of identical auditory tones (1000 Hz) presented through headphones at an intensity of 70 dB above their hearing threshold. Each tone has a duration of 50 ms.

Timing: The Stimulus Onset Asynchrony (SOA) is fixed at 1.5 seconds.

Task: Subjects are instructed to remain relaxed with their eyes open and simply listen to the tones. No motor response is required.

Signal Processing Plan

To ensure high data quality, the research protocol sets a hard limit on the total noise. The specification requires that the combined RMS amplitude of the background EEG and the residual powerline artifact must not exceed 160 mV at the ADC input, to ensure the reliable performance of subsequent artifact rejection algorithms. To extract the N100 ERP waveform, trials meeting this specification are then averaged.

Questions

Write all your answers in the provided text file, following the template

Q1. (2 points) Acquisition and Protocol Timing

a) How many electrodes, in total, must be placed on the subject to ensure a valid and safe recording according to standard practice?

b) What is the Inter-Stimulus Interval (ISI) in milliseconds?

Justify both your answers (max 300 characters total).

Q2. (2 points) Digital Subsystem Parameters

a) What is the quantization step size (or Least Significant Bit, V_{LSB}) of the ADC in microvolts?

b) What is the Nyquist frequency of the system in Hz?

Justify both your answers (max 300 characters total).

Q3. (2 points) Critical Evaluation of the Setup

Is the described acquisition system adequate for this experiment? Identify one potential major issue in the hardware specifications and briefly explain its consequence on the recorded signal.

Justify your answer (max 300 characters).

Q4. (2 points) Total Noise Specification

Does the system, as described, meet the research protocol's specification for total noise? (Hint: If two signals x and y are independent and have zero mean, the variance of their sum is $var(x + y) = var(x) + var(y)$).

Justify your answer by quantifying the total RMS noise at the ADC input and comparing your result to the protocol's specification (max 500 characters).

(End of the test)