Neuroengineering 2024-2025

Exam 10 September 2025

Part II

Solutions

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).

Number of electrodes: 4

ISI (ms): 1450

--- Justification(s) ---

a) The setup requires one recording (Cz) and two reference (A1, A2) electrodes. A ground electrode is also essential to provide a stable common-mode potential for the amplifier's inputs, ensuring they operate within their intended voltage range. This brings the total to 4.

b) ISI = SOA - Stimulus Duration = 1500 ms - 50 ms = 1450 ms.

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).

V_LSB (µV): 152.6

Nyquist frequency (Hz): 64

--- Justification(s) ---

a) The quantization step is the voltage range divided by the number of levels (2^{16}):
$V_{LSB} = (10\ \mathrm{V})/65536 \approx 152.6\ \mu\mathrm{V}$.

b) The Nyquist frequency is half of the sampling frequency (f_s):
$f_{Nyquist} = 128\ \mathrm{Hz}/2 = 64\ \mathrm{Hz}$.

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).

Adequate (Yes/No): No

--- Justification(s) ---

The system has a critical design flaw that will cause aliasing\. The analog filter's high-cutoff frequency is 85 Hz, which is above the system's Nyquist frequency of 64 Hz. Frequencies in the 64-85 Hz range will "fold" into the signal band, causing irreversible distortion.

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).

Combined RMS noise (mV): 153.7

Specification met (Yes/No): Yes

--- Justification(s) ---

EEG RMS:

The differential-mode gain is $G_d = 80\ \text{dB} = 10^{\frac{80}{20}} = 10^4$.
Amplified EEG RMS = $15\ \mu\text{V} \times 10^4 = 150\ \text{mV}$.

Artifact RMS:

The common-mode gain is $G_c = 80\ \text{dB} - 90\ \text{dB} = -10\ \text{dB} = 10^{\frac{-10}{20}} \approx 0.3162$.
The residual artifact peak is $150\ \text{mV} \times 0.3162 = 47.4\ \text{mV}$.
Its RMS value is $47.4/\sqrt{2} \approx 33.5\ \text{mV}$ ([1]).

Combined RMS:

$RMS_{total} = \sqrt{(150)^2 + (33.5)^2} \approx 153.7\ \text{mV}$.

Since 153.7 mV is less than the 160 mV specification, the system meets the requirement.

[1] The RMS value of a sinewave of amplitude A is $A/\sqrt{2}$