

Neuroengineering 2024-2025

Exam 5 June 2025

Part II

Solutions

Q1. (2 points) Electrode Placement (2 points)

- Identify the two optimal 10–20 system electrode locations for capturing SMR changes associated with left- and right-hand motor imagery.
- Are other electrodes necessary to feed all required potentials to the instrumentation amplifier?

Justify (max 300 characters).

Answers:

Optimal locations (10-20 labels): C3, C4

More electrodes (Yes/No): Yes

Justification:

C3 and C4 overlie the primary motor cortices controlling contralateral hands.

Two more electrodes are needed to provide a reference and the ground to the instrumentation amplifier.

Q2. (2 points) ADC Parameters (2 points)

- What is the Nyquist frequency?
- What corner frequency would you choose for the anti-alias filter? (*)
- What is the quantization step size (V_{LSB})?

Justify (max 300 characters).

(*) In your answer take into account the effect of a non-infinite roll-off.

Answers:

- f_{Nyq} : 50 Hz
- f_c : ≈ 40 Hz
- V_{LSB} : 19.53 mV

Justification:

The Nyquist frequency is half the sampling rate ($f_s = 100$ Hz).

A low-pass corner frequency around 40 Hz avoids aliasing (despite the finite roll-off) while preserving beta-band activity (~13–30 Hz).

Step size is full range ($V_R = \pm 2.5$ V) divided by 2^{NBITS} levels (8-bit ADC):

$$V_{LSB} = \frac{(+2.5) - (-2.5) \text{ V}}{2^8} = \frac{5}{256} \text{ V} = 19.53 \text{ mV}$$

Q3. (3 points) PSD Calculation (3 points)

- What should be the window length? Express the length both in milliseconds and in samples.
- What is the time interval between the beginning of a window and the beginning of the following one?
What is the percent overlap between windows?
- How many periodograms are used in the PSD computation at the end of the trial?

Justify (max 400 characters).

Answers:

Window length (milliseconds): 500
Window length (samples): 50
Delta time windows: 100 ms
Window overlap (%): 80%
Number of periodograms: 36

Justification:

To achieve $\Delta f = 2$ Hz, window length $T = \frac{1}{\Delta f} = 0.5$ s = 500 ms = 50 samples

Windows shift = update interval (from the text) = 100 ms = 10 samples.

Overlap = $1 - \frac{100 \text{ ms}}{500 \text{ ms}} = 0.8 = 80\%$

Trial = 4 s; Window shift = 100 ms \rightarrow Number of periodograms = $1 + \left\lfloor \frac{4 \text{ s} - 0.5 \text{ s}}{0.1 \text{ s}} \right\rfloor = 36$ ⁽¹⁾

Q4. (1 point) Final PSD and feature vector (1 point)

- What is the total dimension of the feature vector that would be passed to the classifier?

Justify (max 100 characters).

Answer:

Feature vector length: 24

Justification:

If using alpha (8–13 Hz) and beta (13–30 Hz) with 2 Hz bins:

Range = 8–30 Hz \rightarrow 12 bins per channel ⁽²⁾

Total (2 channels): 24 features

¹ See also solution of exam October 2024, Q3.

² 11 features have also been considered a correct bin count.

- 12 features if we center frequency bins at {0,2,4, ...} Hz
- 11 features if we consider {0,2,4, ...} Hz the bin edges)

Thus 22 features was also a correct answer